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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

(4)

MEMOIRS OF THE GEOLOGICAL SURVEY

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY OF GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1922

WITH

REPORT OF THE GEOLOGICAL SURVEY BOARD

AND

REPORT OF THE DIRECTOR

LONDON:
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S
STATIONERY OFFICE

1923

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REPORT

OF THE

GEOLOGICAL SURVEY BOARD

FOR 1922

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH.

MAY IT PLEASE YOUR LORDSHIPS,

In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our third Annual Report on the work of the Survey and Museum.

1. In our first Report we dealt with the extended scope and opportunities of survey work which had rendered an increase of staff necessary, with the development of the programme of service which was then initiated on the approval of our recommendations and with the appointment of the first instalment of additional officers. In our second Report we noted that authority had been given for the full increase of personnel contemplated. We have now the satisfaction of reporting that successive additions of new members have brought the staff nearly up to the full establishment authorised.

The aim of the work of the Survey is to prepare geological maps of the country, to provide for the continuous collection of systematic records of British Geology, and at the same time to carry out the special investigation of sections of the field which at one time or another acquire fresh scientific or economic importance. The general programme for this work includes (*a*) the continuation of the primary survey of the whole country on a scale of six inches to one mile (" the primary six-inch survey "); (*b*) the systematic revision of early survey work where the need for that is urgent, as it is in not a few areas of great economic importance surveyed from 30 to 50 years ago; (*c*) the collection of reliable records of observations of geological value which emerge in areas that are not at the time under either " primary survey " or " re-survey," the most of these being records which become available in connection with economic exploration or exploitation such as water supply, mining and engineering; and (*d*) the preparation of special reports bringing together for particular subjects information drawn from various areas.

2. In 1922 the staff had not been brought quite up to the full strength, and as the increases were considerable, the programme

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for that particular year was to some extent conditioned by the need of affording to recent recruits suitable opportunities of becoming familiar with those aspects of Survey work which were new to them.

3. Before dealing with the progress made on the expanded programme for systematic " Primary Survey " and " Re-survey " work, we desire to refer to three features in the activities of the year which were all necessary to bring the war-time work of the Survey into due relation with the programme of to-day.

The interruption caused by the outbreak of war gave rise to many loose ends in the primary six-inch survey work then in progress. During the war, the Survey officers were all engaged either on military duties or on special geological service, whether in connection with military requirements or with a view to the utilisation of the mineral resources of Great Britain. The Special Reports of the Survey on these mineral resources have found a wide public, and have proved of much value. Under present economic conditions some of them have little immediate application, but many are of direct and continuing importance, and all are permanent records of material use. These records are being kept, as far as practicable, up to date, and each Report will be revised when a fresh issue is required. Some such re-issues and some notable additions either published or prepared in 1922 are mentioned in the Director's Report. This series, put in hand during the war, is likely to be of much use in placing before the public in convenient form sections of the collected records which are always available for reference at the Offices of the Survey.

Again, in several areas field-work was left unfinished or unpublished at the outbreak of war. This has been taken up again and is being completed as rapidly as possible. The preparation of those maps and memoirs which had been unduly protracted has been expedited and is now completed or approaching completion. Full facilities for publication have been restored, so that arrears of issue of Survey records are diminishing rapidly.

Owing to special increase of personnel in the course of the last three years, the staff at present includes an unusually large number of men who, while selected in respect of the high standard of attainment and of aptitude which they had shown as students and workers in geology, had still much to learn in the methods and requirements of work in the Survey. In these matters they have to make good under the guidance and supervision of their District Geologists, and we are pleased to find that the younger members of the staff to-day appear likely to maintain the credit of the Survey. At the same time it ought to be noted that the satisfactory output of work, both in field survey and in publication of results, which marks the records for the year has been attained despite the undoubted handicap imposed by the relatively high proportion of men in the early years of their service.

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4. Seven Field Units have been engaged on surveys in the Districts prescribed by the programme approved for the work of the year, viz.:—

The four field units in areas under survey in the previous years :—

(*a*) London and South Eastern District (primary six-inch survey).

(*b*) Midland District—with North Wales (primary six-inch survey).

(*c*) South West Highland District (primary six-inch survey) summer part of field season; and Ayrshire Coalfield Revision—remainder of season.

(*d*) North Highland District (primary six-inch survey) summer part of field season; and Central Coalfield of Scotland Revision—remainder of season.

The three field units which commenced re-surveys of the following areas in 1921 :—

(*e*) Northumberland and Durham District.

(*f*) Cumberland District.

(*g*) Lancashire District.

The Director's Report gives particulars of the work carried out in each of these areas in the course of the year. The establishment of local headquarter offices in districts which are at a distance from both London and Edinburgh has proved of much advantage both in respect of economical working and in bringing the staff of the Survey into closer relation with those interested and helpful in their work in the areas. It was not found possible to begin the revision of the Fifeshire and Yorkshire Coalfields, but before the close of the year a District Geologist was selected for each of these areas, and after these officers have completed their maps and notes for the areas on which they have been engaged, they will take up the revision work for which they are now detailed.

5. The officers of the Petrographical, Palæontological and Chemical Departments at the headquarters offices have co-operated with the field staff on questions that arose in the course of the work of survey and in the preparation of sections of memoirs in which one or other of these departments was largely concerned. They have also dealt with such current enquiries from other Government Departments, public services, etc., as fell within their special fields.

Attention has been given to opportunities of obtaining information from bore-holes in progress, whether in areas under survey or elsewhere, and the collection of records bearing on mining and on underground water supply is steadily increasing.

6. Important additions have been made during the year to the collections in the Museum of Practical Geology and to the Library. Details of these are given in the Director's Report,

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which also sets out certain new developments in the way of arranging collections at the Museum for exhibition to the public.

7. The Director draws attention in his Report to the inconvenient accommodation for the increased staff at Edinburgh. We are in complete sympathy with the Director's views, and we hope that on the expiration of the lease for the premises in George Square, it may be possible to arrange for more suitable quarters for the staff centred at Edinburgh.

8. In several sections of its enquiries and research investigations the Survey has continued to take advantage of the professional assistance of geologists outside the Survey who have special knowledge and experience of the matters to be discussed. The Director, in his Report, refers to some of the contributions to its publications which the Survey owes to these specialists, and his statement is one which well illustrates the advantage of associating such experts with the Survey from time to time in the interpretation and exposition of particular sections of its results.

Mining engineers and mining companies, public authorities and local geological workers give much voluntary help to the officers of the Survey at work in the field. With but rare exceptions, information as to results of borings and exploratory operations, so far as bearing on mining, water supply and general geological investigations, is made available fully and readily.

9. The programme of field work for 1923 is :—

(*a*) to continue the primary survey on the six-inch scale in the London and South Eastern District, in the Midlands (Wolverhampton district), in the West Highlands (Ardnamurchan and adjacent districts) and in the North Highlands (Sutherlandshire around Altnaharra);

(*b*) to continue revision work on the six-inch scale in the following districts where revised editions of the original six-inch maps are now required :—Lancashire, Cumberland, Northumberland, Yorkshire, Ayrshire, and Central Coalfield of Scotland (Lanarkshire, Stirlingshire and Clackmannanshire);

(*c*) to start the revision of the six-inch maps of Yorkshire and Fifeshire, and to collect all available geological information regarding the Concealed Coalfield of Yorkshire for a new edition of the memoir on that field;

(*d*) to continue the preparation of Reports on British Mineral Resources, including new editions of Reports already published, when occasion arises; to collect and prepare for publication further information regarding underground water supplies, and to obtain records and examine cores of borings for water and for minerals.

F. G. OGILVIE,
Chairman.

May, 1923.

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REPORT

OF THE

DIRECTOR

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1922

During the year 1922 several changes have taken place in the staff of the Geological Survey and Museum. Following upon a competitive selection by the Civil Service Commissioners held in August four additions were made to the list of geologists. Officers appointed to the Survey rank as geologists on probation for two years, after which time, if approved, they receive permanent appointments. In November Mr. C. E. N. Bromehead and Mr. C. H. Dinham were appointed District Geologists and they have been entrusted with the task of preparing for the revision of the survey of the Yorkshire and Fifeshire districts which will be begun in 1923. Till the end of the year both of these officers were to a large extent occupied with completing their maps and notes for the memoirs of the districts in which they had been working during the past field season.

A reorganisation of the Auxiliary Staff of the Survey and Museum was effected in November; three classes are now recognised in these grades, viz.:—Technical Assistants (1st Class), Technical Assistants (2nd Class) and General Assistants, and new conditions of pay have been established for these ranks. No appointments have been made to the Auxiliary Staff during 1922.

In Edinburgh the increase of staff has necessitated the provision of additional accommodation, and the rooms in Sheriff Court Buildings, George IV Bridge, which were for many years the offices of the Geological Survey (Scotland) have been assigned to it again by H.M. Office of Works. The inconvenience of having part of the geological staff working in a separate building is considerable, and the present arrangement can only be regarded

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as temporary. The need of new accommodation in Edinburgh suitable for the staff and the collections of maps, rocks, and fossils, in one building, will have to be recognised when the lease of the office in George Square expires.

Owing to the large number of new appointments to the staff of geologists during the last two years a heavy burden has rested on the district geologists who have the duty of training beginners in field work and maintaining the standard of surveying at its old level. This work, however, is being successfully overtaken and all, except one, of those who have completed the probationary period have been accepted for the service. The district geologists also are, in many cases, of recent appointment, or are in charge of new districts. These circumstances tend to retard the production of finished work. The Geological Survey, in fact, within the last three years, has been expanded and rearranged, and numerous alterations have been made in its methods and its fields of work, although as far as possible the old and well tried lines of progress have been followed. A good start has been made with the survey of the new districts; viz.: Cumberland, Northumberland and Lancashire. In each of these areas the district geologists in charge have assiduously collected mining information, and have got into touch with the industrial interests concerned with geological problems. The revision of the six-inch mapping has proceeded smoothly, and the publication of six-inch and one-inch maps is now to be started. Three one-inch sheets in Cumberland and three in Northumberland are reported as completed and the dry-proofs are being prepared for engraving. A few six-inch coalfield maps in each of these districts are also ready to be dry-proofed, but the mining information which has to be compiled in the northern coalfields is often very heavy owing to the long period which has elapsed since the last edition of the Geological Survey map was published, and progress with the work is necessarily slow. The work of the staff in the new districts, in fact, has been largely taken up in the study of the correlation and sequence in each field, and, until these preliminary investigations are completed, the preparation and publication of maps is often impossible. In Northumberland and Cumberland each unit has been investigating two kinds of ground: one in the worked coalfields, where there is much information to be obtained from bores and plans; and the other in the more purely agricultural districts, where mining has not been so actively prosecuted and which are often more suitable for the training of beginners in field geology. In Lancashire it has been found necessary to make a very careful investigation of the correlation of the various grit beds and coal seams and a special study of the fossil zones before arriving at definite conclusions regarding the sequence of the rocks and the thickness of the recognised subdivisions.

The help accorded to the Survey officers by mining engineers and local geologists has been of the greatest value in all these districts, and has greatly accelerated the progress of the work.

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In 1921 the North Wales coalfields and the Midland districts were consolidated into one district under Mr. T. C. Cantrill. Unfortunately, this officer has been prevented by ill-health from participating in the field work during 1922, and special arrangements have had to be made to carry on the work. Satisfactory progress, however, can be reported, as the Liverpool Map and Memoir (Sheet 96) are passing through the press and three other maps and memoirs, Wem (Sheet 138), Birmingham (Sheet 168) and Flint (Sheet 108) are being prepared for publication. There still remain in this district a number of maps on which work has been begun but not completed, a state of affairs to some extent resulting from the dislocation of work arising from the war and the subsequent changes of personnel, but every effort is being made to secure early completion and publication of the work.

In the London district three one-inch sheets were completed during the year: Hertford (Sheet 239), North London (Sheet 256), and Dartford (Sheet 271), and the maps can now be dry-proofed and the memoirs written. The work left unfinished at the outbreak of war has accordingly been brought to completion. The arrears of old work in this district are now greatly reduced, and publication will be abreast of the state of the field survey as soon as the maps and memoirs now in hand have passed through the press. This unit has published two memoirs during the year, London (special map) and Beaconsfield (Sheet 255); and the Aylesbury Memoir (Sheet 238) is printed off and will be published shortly.

In Scotland the training of young geologists presents special difficulties owing to the variety and complexity of the ground surveyed. Each member of the staff spends part of the year in the coalfields and adjacent districts and part in the Highlands or Western Islands. A knowledge of petrology is often of great advantage in the metamorphic and volcanic areas. Progress in consequence may be slow if the ground is intricate and the time of district geologists and senior geologists is taken up in looking after the beginners. Attention has specially been directed during last season to finishing sheets that have been some time in hand. The Scottish sheets are twice as large as the English sheets and require a longer time to survey. In the Western Islands two sheets have been finished during the year, Tiree (Sheet 42) and Coll (Sheet 51), and the survey of the outlying islands to the west of Mull is now finished. The maps and memoirs are to be put in hand as soon as more urgent work is despatched. On the mainland the survey of Ardnamurchan and the Strontian district (Sheet 52) has now been going on during parts of two field seasons, and, though the geology is very intricate, satisfactory results are being attained.

In the North-East Highlands the Lairg Sheet (102) was finished. The adjacent sheet to the east, Brora (103), was surveyed many years ago and is not up to present day standards. Consequently it has been decided to make some revision of

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that ground in order to complete the information and render it possible to publish a colour-printed map of that district along with the adjoining maps. It is expected that this will be accomplished in the coming field season. For some years Dr. Lee and Mr. Buckman have been studying the fossiliferous Jurassic rocks of the Brora and Helmsdale districts and the results of their work will be available for publication in the new map and memoir. Some progress was made also in the survey of the Altnaharra Sheet (108) which, with Achintoul (109), will be now pushed forward as rapidly as circumstances allow. These are the only remaining sheets of Sutherlandshire to be published as geological maps. A special geological map of the complicated Assynt area, on the scale of one inch to one mile, is in the press.

In the Scottish coalfields the revision of North Ayrshire has been continued and one-inch Sheet 22 (Kilmarnock), which has been a very interesting and difficult piece of work, is nearing completion. Meanwhile the publication of the six-inch coalfield maps of that area is being rapidly advanced and a number of the Sheets are now issued or in the press. A memoir on the valuable Bauxitic Clay deposits of the Saltcoats and Kilwinning district was published during the year, as sufficient confidential information had been released by mining engineers and others interested in that field to make possible the publication of the more important facts and the chemical analyses. It has been decided to issue special economic memoirs on the Ayrshire coalfield similar to those that have been published on the Central Coalfield of Scotland, and the first part of the memoir on the Economic Geology of North Ayrshire is now being written. It describes the Dalry, Beith and Stewarton districts, including about twenty three six-inch quarter sheets. This was formerly an important iron-mining area and it has important deposits of limestone, fireclay and coal. The second part of this memoir will follow containing the description of the Carboniferous rocks of the Kilmarnock and Irvine districts.

The Central Coalfield of Scotland includes the coal mining districts of Renfrewshire, Stirlingshire, Dumbartonshire, Linlithgowshire and most of Lanarkshire. The revision of the maps of this field was well advanced before the war put a stop to publication, and when the war ended much additional information had become available. The new six-inch maps are now practically all published and the few remaining ones will shortly be issued. The principal one-inch map of this district (Sheet 31) is being engraved, but it is very complicated and consequently there has been delay. Field work is now being carried on in the smaller outlying coalfields of Muirkirk, Douglas and Alloa. The sixth part of the Memoir on the Economic Geology of the Central Coalfield of Scotland is nearly completed in manuscript. The special memoir on the Glasgow district is sold out and a revised edition must be taken in hand.

The investigation of British mineral resources which has taken up a large part of the time of the staff since 1914 has been

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continued during 1922, and several new volumes of the Special Reports have made their appearance. One of these is an account of Scottish Cannel Coals and Lignites (Vol. XXIV). Two others deal with Lead and Zinc Ores (Vol. XX—North Cardiganshire and West Montgomeryshire and Vol. XXIII—West Shropshire and North Wales, Pre-Carboniferous). A third edition of the Barytes and Witherite report has been issued. Several other volumes of this series are in the press and will be published soon. Two memoirs describe the Lead and Zinc Ores of the North of England and Derbyshire. These will complete the descriptive accounts of British resources of Lead and Zinc Ores. A new edition of the Fluorspar report (Vol. IV) was published and a third edition of the Tungsten and Manganese report (Vol. I) is in the press. The first part of the report on Copper Ores of England is also printing (Vol. XXVII), and the second part is in preparation. A memoir on the chemistry of British Fireclays, containing many analyses made in the Survey's laboratory, is now in hand. A memoir on the microscopic and mineralogical characters of British iron ores is in contemplation. The first edition of the report on the Hæmatites of Cumberland is nearly sold out and a new edition is being prepared.

When these reports have been published it will appear that the mineral resources of Great Britain have been thoroughly examined, and though the accounts are necessarily brief they are up to date and reliable. Every British active mine working mineral deposits (apart from coal and oil shale) will have been visited by the Survey geologists during the last few years. The fact that several of the reports have passed through two or three editions shows that they have been appreciated and the information has been found useful both by the mining industry and the general public. The outburst of activity due to demand under war conditions led to the opening of many mines, and this afforded a very favourable opportunity for collecting information, much of which would have been lost if the work of preparing the reports had not been undertaken during the period when the mines were active. The state of the mineral market of late has not been such as to encourage mining in Britain, and many mines have recently closed down.

The mining plans of the older mines which have not been worked during or since the war have been examined where accessible. Many particulars have also been collected regarding the history of mining in the various parts of Britain where mineral ores have been produced in former times.

As the reports on mineral resources are sold out new editions will be prepared and a periodical revision of the information will be undertaken. In such cases all the active mines are visited. The assistance of the mining engineers in charge is readily given and any new developments are placed on record. Specimens of the ores have been collected and deposited in the Museum of Practical Geology, where they form a valuable mass of material representing the economic minerals of Great Britain.

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Useful information regarding water supply from underground sources is frequently received, and the collection of records of wells and borings for water is constantly increasing. This information is incorporated into the ordinary sheet memoirs wherever it appears to be of sufficient importance; for example the Liverpool memoir and the Coventry memoir, now in the press, contain chapters on underground water supply. Most of it, however, is reserved for the special Water Supply memoirs which deal with county areas and not with the individual geological Sheets. One water supply memoir has been published during the year (Cambridgeshire, Huntingdonshire and Rutland) and three others have been completed in manuscript, viz. :— Wiltshire, Dorsetshire and Gloucestershire. This completes the description of practically the whole of the counties of the south and east of England, where the Secondary and Tertiary rocks furnish important supplies of water through wells and borings. Attention is now to be directed to some of the Midland Counties where the rapid growth of industrial populations has occasioned increased demands for pure water, and where it cannot readily be obtained from surface supplies. Leicestershire and Derbyshire will probably be the first of these counties to receive attention. The services of Mr. W. Whitaker, F.R.S., have again been enlisted for this work and his long experience and intimate knowledge of the subject have been most freely placed at the disposal of the Survey in preparing new memoirs of this series. Mr. Richardson has written the memoir on Gloucestershire water-supplies and from personal familiarity with the district has been able to supply particulars of practically every underground water supply in that county.

In these and other cases advantage has been taken of the special qualifications possessed by geologists not on the Survey, but expert in various departments of geological work, and willing to undertake the preparation of memoirs on their special fields of research. Mr. Osborne White, during the year under consideration, has written an account of the geology of the country south and west of Shaftesbury, which is now passing through the press. The old hand-coloured one-inch sheets of this area (Old Series 15 & 18) have been adapted for colour-printing as New Series Sheet 313, and as it proved desirable to revise the information in certain parts of the district Mr. Dines and Mr. Hollingworth, under the superintendence of Mr. Howe, have mapped the gravels and alluvial deposits, and the results of their work will be shown on the new map.

For many years it has been recognised that a systematic description of the fossil plants of the British Carboniferous rocks was very much needed in connection with the identification of the horizons of coal seams and other strata in the British coal-fields. Dr. Robert Kidston, who has devoted many years to palæobotanical research on these problems, and whose name is sufficient guarantee for the accuracy and thoroughness of the work, has volunteered to undertake the preparation of a memoir

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on this subject. It is intended to publish this monograph in parts, which will probably be ten in number, each containing a description of a group of species, with illustrative plates, and full records of the horizons and localities in Britain at which specimens have been obtained. Three parts are now in the press: they have from twenty to thirty plates for each part and it is expected that they will be issued to the public early in 1923. This palæobotanical monograph will form a valuable supplement and companion to the memoirs which the Geological Survey has been publishing on British coalfields and will be all the more useful because palæobotanical details have not generally been included in the geological memoirs, as, without descriptions and figures, it was difficult to show adequately the bearing of the evidence obtained from fossil plants on the geological sequence.

Among other specialists who have assisted the Geological Survey with geological and palæontological information during the year 1922 we may mention Mr. Buckman, who has determined a large number of ammonites and brachiopods from Brora and Helmsdale districts; Dr. Spath, who has determined Cretaceous ammonites; Miss Elles, graptolites; Professor Watson, Carboniferous vertebrates; and Mr. T. H. Withers, cirripedes.

In the Museum of Practical Geology attention has specially been directed to the proper curation and exhibition of the growing collection of British economic minerals and rocks, such as the fireclays, abrasives, ganisters and silica rocks, roadstones and iron ores. The building stones collections have been cleaned and in part revised. A new case has been arranged to show typical examples of Survey maps and memoirs, and the other recent publications of the Survey. The latest edition of the quarter inch map of England and Wales has been mounted and is exhibited on one of the walls. A new edition of the Short Guide to the Museum is now on sale.

Many requests are received from scientific societies, schools and clubs, for demonstrations on the exhibits in the Museum, and, although no official demonstrator has been appointed, these requests are always acceded to. Members of the Survey and Museum staffs undertake the task of providing these demonstrations, often in their private time, and their services must be gratefully acknowledged. The favourite subjects are such as the geology of the London district, or of the south-east of England, the exhibited collections of building stones, roadstones, gems and ores. The attendance at each demonstration is necessarily limited owing to exigencies of space. Fifty-nine demonstrations of this type were given during 1922 and the demand for them is increasing. They undoubtedly have educational value and are much appreciated.

Large additions to the library continue to be made, and the arrears of foreign publications which had been unavoidable during the war are now diminishing. A very large series of maps and memoirs has been obtained from the Geological Survey of

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Prussia, and our set of their publications is now practically complete.

The library is extensively used by geologists, engineers, and travellers, especially for its collection of geological maps and memoirs on regional geology. Lists of the additions to the library are now posted at the entrance to direct attention to the latest publications received. Over five hundred geological maps of all parts of the world were added during 1922.

I.—SURVEY WORK

(1)—ENGLAND AND WALES

Field-work

London District.—Field survey was completed in Sheets 239 (Hertford), 256 (North London), 271 (Dartford), and continued in Sheet 257 (Romford) by Messrs. Bromehead, Dines and Edmunds, with Mr. Dewey as District Geologist.

Shropshire, Warwickshire and Staffordshire District.—Work was completed in Sheets 138 (Wem) and 168 (Birmingham), and continued in Sheets 153 (Wolverhampton) and 167 (Dudley) by Messrs. Pocock, Whitehead, and Robertson, under the superintendence of Mr. Cantrill, District Geologist.

Lancashire District.—Work was continued in Sheet 76 (Rochdale) by Mr. Wright, District Geologist, and Messrs. Sherlock, Wray, Lloyd, Tonks, and Marsden. Small areas in the adjacent Sheets 67 (Garstang), 68 (Clitheroe), and 75 (Preston) were also examined.

Cumberland District.—Work was completed in Sheets 11 (Longtown), 16 (Silloth), and 17 (Carlisle), continued in Sheet 28 (Whitehaven), and commenced in Sheet 18 (Brampton) by Messrs. Dixon, Eastwood, Trotter, Hollingworth, and Tonks, under the superintendence of Mr. Bernard Smith.

Northumberland and Durham District.—The revision was completed of Sheets 1 (Norham), 2 (Berwick), and 4 (Holy Island). Work has been continued in Sheet 3 (Ford) and commenced in Sheets 6 (Alnwick), 9 (Rothbury), 14 (Morpeth), 20 (Newcastle-on-Tyne) by Mr. Carruthers, District Geologist, with Messrs. Dinham, Burnett, Fowler, Maden and W. Anderson.

Indoor Work

The manuscripts of the following memoirs are being written or edited for publication :—

Special Reports on the Mineral Resources of Great Britain :—
Copper Ores of the Midlands, the Lake District, and North Wales.
Refractory Materials : Fireclays. Chemistry and Physical Tests.
Water Supply of Wiltshire.
Water Supply of Gloucestershire.
Water Supply of Dorsetshire.
Soils and Subsoils with especial reference to London and its neighbourhood (3rd edition).
Guide to the Goring Model.
Explanations of Sheets 11 (Longtown), 16 (Silloth), 17 (Carlisle), 108 (Flint), 138 (Wem), 168 (Birmingham), 239 (Hertford), 256 (North London), 271 (Dartford), 318 and 333 (Brighton and Worthing).

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The following maps and memoirs were published or passing through the press in 1922 :—

I.—MAPS

Published.

¼-inch to 1 mile :—

Sheet 15 (Birmingham, Northampton, Gloucester, Oxford, Worcester). New Edition.

1 inch to 1 mile :—

Sheet 154 (Lichfield, drift edition), Sheets 226 and 227 (Milford, drift and solid editions), Sheet 231 (Merthyr Tydfil, new drift and solid editions), Sheet 244 (Linney Head, solid edition, hand-coloured), Sheet 245 (Pembroke, solid edition, hand-coloured), Sheet 249 (Newport, new drift and solid editions), Sheet 255 (Beaconsfield, drift edition).

6 inches to 1 mile :—

Derbyshire, 26 N.W.; 35 N.W.

Staffordshire, 45 S.W., S.E.; 51 N.W., N.E., S.W., S.E.; 57 N.W., N.E., S.W., S.E.; 63 N.W., N.E., S.W., S.E.

Warwickshire, 2 N.E. (Staffs. 59 N.E.), S.E. (Staffs. 59 S.E.); 5 N.E. (Staffs. 65 N.E.), S.E.; 9 N.E., S.E.; 10 N.W., N.E. (Leics. 41 N.E.), S.W., S.E.; 11 S.W. (Leics. 42 S.W.); 15 N.E., S.E.,; 16 N.W., N.E., S.W., S.E.; 17 N.W., S.W.; 20 N.E., S.E.; 21 N.W., N.E., S.W., S.E.; 22 N.W., S.W.

In the press, engraving or colour-printing.

1 inch to 1 mile :—

Sheet 96 (Liverpool), Sheet 108 (Flint), Sheet 169 (Coventry), Sheet 238 (Aylesbury), Sheet 271 (Dartford), Sheet 313 (Shaftesbury).

6 inches to 1 mile :—

Cheshire, 30 N.W. and 30A N.E., 30 N.E.

Denbighshire, 20 N.E. (Flint. 16 N.E.), S.E. (Flint. 16 S.E.); 21 S.W. (Flint. 17 S.W.), S.E.

Flintshire, 2 N.W., (2 N.E. and 2A S.E.), S.W., S.E.; 3 S.W.; 5 N.E.; 6 N.W., N.E., S.W., S.E.; 9 N.E., S.E.; 10 N.W., S.W., S.E.; 13 N.E., S.E. (Denbigh. 15 S.E.); 14 N.W., N.E., S.W.; 17 N.W.

Leicestershire, 28 N.W. (Staffs. 60 N.W., Warw. 3 N.W.).

Warwickshire, 3 S.W. (Leics. 28 S.W.); 6 N.W. (Leics. 34 N.W.), 6 S.W.

Copies of the following six-inch sheets, which are not to be published, were deposited in the Library for public reference :—

Cheshire, 22 N.E., S.W., S.E.; 23 N.W., S.W.; 31 N.W.; 34 N.W. (Salt mines information only).

Dorset, 14 N.E., S.E.; 24 N.E. ; and parts of 3 S.E.; 4 S.W.; 7 N.E.; 8 N.W., N.E., S.W., S.E.; 13 S.E.; 14 N.W., S.W.; 22 N.W., N.E.; 23 N.W., N.E.; 24 N.W.

Hertfordshire, 39 S.W.

Lancashire, 106 N.W. (part), N.E. (part), S.W., S.E. (part); 113 N.W., N.E. (part), S.W. and S.E. (part).

Middlesex, 1 N.E., S.E.

II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1921. 189 pp.; 6 text-figures. 1922. Price 5*s*. net.

Special Reports on the Mineral Resources of Great Britain :—

Vol. II.—Barytes and Witherite. By G. V. Wilson, B.Sc., T. Eastwood, A.R.C.S., R. W. Pocock, B.Sc. D. A. Wray, M.Sc., and

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T. Robertson, B.Sc., with contributions by H. G. Dines, A.R.S.M. 119 pp.; 6 plates; 1 text-figure. *Third Edition.* 1922. Price 3*s.* net.

Vol. XX.—Lead and Zinc. The Mining District of North Cardiganshire and West Montgomeryshire. By O. T. Jones, M.A., D.Sc., Professor of Geology and Mineralogy, Victoria University, Manchester. (*Late of the University College of Wales, Aberystwyth*). 207 pp.; 1 coloured geological map; 27 plates; 4 text-figures. 1922. Price 7*s.* net.

Vol. XXIII.—Lead and Zinc Ores in Pre-Carboniferous Rocks of West Shropshire and North Wales. Part I.—West Shropshire. By Bernard Smith, M.A. Part II.—North Wales. By Henry Dewey and Bernard Smith, M.A. 95 pp.; 13 text-figures. 1922. Price 3*s.* net.

The Water-Supply of Cambridgeshire, Huntingdonshire and Rutland from Underground Sources. By William Whitaker, B.A., F.R.S. 157 pp.; 1 text-figure. 1922. Price 7*s.* net.

The Geology of the London District. (Being the area included in the four sheets of the Special Map of London). By Horace B. Woodward, F.R.S. *Second Edition.* Revised by C. E. N. Bromehead, B.A., with notes on the Palæontology by C. P. Chatwin. 99 pp. 1922. Price 1*s.* 6*d.* net.

The Geology of the Country around Beaconsfield. (Explanation of Sheet 255). By R. L. Sherlock, D.Sc., A.R.C.Sc., and A. H. Noble, M.C., M.A.; with contributions by J. Pringle. 59 pp.; 1 plate; 2 text-figures. 1922. Price 2*s.* net.

A Short Guide to the Museum of Practical Geology, Jermyn Street, London, S.W. 1. 44 pp. *Third Edition.* 1922. Price 2*d.* net.

In the press.

Special Reports on the Mineral Resources of Great Britain :—

Vol. I.—Tungsten and Manganese Ores. *Third Edition.*

Vol. IV.—Fluorspar. *Third Edition.*

Vol. XXV.—Lead and Zinc Ores of Northumberland and Alston Moor.

Vol. XXVI.—Lead and Zinc Ores of Durham, Yorkshire and Derbyshire, with notes on the Isle of Man.

Vol. XXVII.—Copper Ores of Cornwall and Devon.

Memoirs of the Geological Survey of Great Britain :—

Palæontology. Vol. II. Fossil Plants of the Carboniferous Rocks of Great Britain. Parts 1, 2, and 3.

The Concealed Mesozoic Rocks in Kent.

The Geology of Liverpool, with Wirral and part of the Flintshire Coalfield. (Explanation of Sheet 96.)

The Geology of the Country around Coventry, including an account of the Carboniferous Rocks of the Warwickshire Coalfield. (Explanation of Sheet 169.)

The Geology of the Country around Aylesbury and Hemel Hempstead. (Explanation of Sheet 238.)

The Geology of the Country South and West of Shaftesbury. (Explanation of Sheet 313.)

(2)—SCOTLAND

Field-work

West Highlands.—Sheet 42 (Tiree) was commenced and finished, 51 (Coll) was finished and work was continued in Sheet 52 (Ardnamurchan), by Messrs. Richey, Eyles, and A. G. MacGregor under Mr. E. B. Bailey, District Geologist.

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North-East Highlands.—Mr. M. Macgregor, District Geologist, with Messrs. Wilson, Haldane, Ross and Phemister, completed the survey of Sheet 102 (Lairg) and continued that of Sheet 108 (Altnaharra). Messrs. Macgregor, Read, and Haldane also revised parts of Sheet 103 (Brora) with a view to replacing the old hand-coloured map published in 1896.

Ayrshire.—Mr. E. B. Bailey, District Geologist, and Messrs. Anderson, Richey, Eyles, Simpson, and A. G. MacGregor have continued survey work in Sheets 22 (Kilmarnock), and 14 (Ayr).

Lanarkshire (including Muirkirk), Clackmannanshire and Stirlingshire) —Mr. M. Macgregor, District Geologist, and Messrs. Wilson, Read, Haldane, Ross, and Phemister, have continued the revision of Sheets 15 (Muirkirk), 23 (Lanark), and 39 (Stirling).

Indoor Work

The manuscripts of the following memoirs are being written or prepared for publication :—

Economic Geology of the Central Coalfield of Scotland :—
Area VI.—(Bathgate).
Economic Geology of the Ayrshire Coalfield :—
Area I.—(Dalry, Saltcoats, Kilwinning, and Kilmaurs).
Explanations of Sheets 102 (Lairg), 44 (Oban and Mull), 86 and 96 (Portsoy, Huntly, Banff).

The following maps and memoirs have been published or are passing through the press :—

I.—MAPS

Published.

1 inch to 1 mile :—
Sheet 37 (Mid Argyll).

6 inches to 1 mile :—
Ayrshire, 8 N.E.; 11 N.E.; 12 N.W.
Lanarkshire, 8 S.W.; 9 S.W.; 11 N.E.; 13 S.W., S.E.; 14 S.W.; 16 N.E.; 17 N.E., S.W.; 18 N.E., S.W.; 24 S.W., S.E.; 25 N.W.
Renfrewshire, 7 N.E., S.E.; 11 N.E., S.E.; 12 S.W.; 16 N.W., N.E.; 17 N.W.
Stirlingshire, 25 S.W.; 29 N.E.

In the press, engraving or colour-printing.

1 inch to 1 mile :—
Special Map of Assynt District, Sheet 86 (Huntly), Sheet 96 (Banff), Sheet 84 (Lower Findhorn and Lower Strath Nairn), Sheet 54 (Moor of Rannoch), Sheet 44 (Mull), Sheet 31 (Falkirk), Sheet 16 (Moffat), Sheet 3 (Stranraer, Port Patrick), Sheet 2 (Whithorn, Burrow Head), Sheet 1 (Mull of Galloway).

6 inches to 1 mile :—
Ayrshire. 8 S.W., S.E.; 11 N.W., S.W., S.E.; 12 S.W.; 16 N.W. and S.W., N.E., S.E.; 17 N.W., N.E., S.W., S.E.; 23 N.W., N.E.
Stirling 23 S.E.; 28 S.E.; 29 N.W., S.W.; 33 N.E.

Copies of the following six-inch sheets, which are not to be published, were deposited in the Office for public reference :—

Argyllshire, 21 S.E.; 22 N.W., S.W.; 37 N.W., S.W.
Ayrshire, 49 N.E., S.E.; 70; 73 N.W., N.E., S.E.; 74 N.W., N.E.
Dumfriesshire, 31; 32; 33; 38 N.E.; 39; 40; 47 N.W., N.E.; 48 N.W., N.E.; 49; 55 N.E., S.E.; 60 N.E., S.E.; 61; 62; 63; 64 N.W., S.W.
Kirkcudbrightshire, 27; 31; 32; 33; 34; 39; 40; 41; 44; 45; 46; 47; 49; 50; 51; 52 N.W., N.E., S.W.; 54.

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II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain for 1921. *See* p. 13.

The Ayrshire Bauxitic Clay. By G. V. Wilson, B.Sc. 28 pp.; 1 plate; 2 text-figures. 1922. Price 1*s.* 6*d.* net.

Special Reports on the Mineral Resources of Great Britain :—

Vol. XXIV.—Cannel Coals, Lignite and Mineral Oil in Scotland. By W. Gibson, D.Sc., from contributions by J. S. Flett, F.R.S., E. M. Anderson, M.A., G. W. Lee, D.Sc., and M. Macgregor, M.A., 73 pp.; 6 text-figures. 1922. Price 2*s.*

In the press.

The Geology of the Lower Findhorn and Lower Strath Nairn, including part of the Black Isle near Fortrose. (Explanation of Sheet 84 and part of 94 Scotland).

The Geology of Corrour and the Moor of Rannoch. (Explanation of Sheet 54).

II.—GENERAL WORK

A.—PETROGRAPHICAL DEPARTMENT

In addition to the ordinary routine work of the Petrographical Department Dr. Thomas has been employed mainly on the preparation of a petrological account of Sheet 44 (Mull), which, with the co-operation and assistance of Mr. Bailey, he has now completed. He has furnished a petrological description of the Pre-Cambrian and Post-Cambrian igneous rocks of Nuneaton for publication in the memoir on that district.

The petrology of Sheet 54 (Moor of Rannoch) by Dr. Thomas and Mr. Read has been completed and an account of the rocks prepared for the memoir now in the press.

In co-operation with Mr. Radley, at the request of the Building Research Board, Dr. Thomas undertook an investigation to test methods for determining the proportion of slag in Portland Cement.

During the year a paper by him on the Xenolithic Intrusions of Mull was published by the Geological Society of London.

The Collections have benefited by several presentations. Mr. Shannon presented a collection of igneous rocks with sections from the Torquay district, and late in the year Sir A. H. McMahon gave to the Department the English collection of rocks and sections illustrative of General McMahon's work in the West of England. The registration of this last acquisition is in hand but not yet completed. The additions to the collections of sliced rocks total 539, made up as follows :—English 135, Scottish 377, Irish 5, Foreign 22.

The number of rocks and corresponding sections registered in the collections up to the end of the year are :—

English	12,372
Scottish	21,430
Irish	445
Foreign	2,487
Total	36,734

The rock sections registered during the year total 539, of which 464 were made in the London Office. Of a smaller number prepared in Scotland, 26 have been forwarded to headquarters for registration.

The work of despatching rocks and sections from the London office to officers of the Survey and private individuals for study has been unusually heavy, no less that 686 rocks and 2,862 sections having been dealt with.

Rock specimens were collected during the year to the number of 1,059, from the counties of Argyll, Ross, Sutherland, Ayr, Renfrew, Wigtown, Kirkcudbright; 626 of these were collected from districts in

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which the geologists are surveying; the remainder were collected in connection with the preparation of colour-printed maps to replace the old hand-coloured issues. Rock sections to the number of 346 were made by Mr. Eckford: only a part of this series has yet been registered.

B.—PALÆONTOLOGICAL DEPARTMENT

England and Wales

During the year 4,800 specimens of fossils have been added to the collections, 800 of which were acquired by purchase. Fossil collecting has been carried on principally in Cumberland, Lancashire, Shropshire and the counties near London, in the course of current Survey work. Mr. Pringle has made numerous field-examinations, principally of Cretaceous, Jurassic, and Carboniferous rocks, in connection with the preparation of sheet memoirs. He has dealt with questions relating to water-supplies and has examined materials from various deep borings. The officers of the department have received many miscellaneous enquiries and have carried out palæontological investigations in connection with the preparation of memoirs. They have also been much occupied with editorial work.

Scotland

During the year the number of fossils collected and registered amounted to 2,535: of these 1,072 were collected from borings and natural exposures in Carboniferous rocks and have proved of much service in the identification of horizons in trial borings for coal; 611 fossils were obtained from the Jurassic area of Ardnamurchan, and 20 from the Pleistocene deposits of Ayrshire.

Mr. Tait collected 832 fossils from the Carboniferous rocks of Northumberland, now under revision by the Newcastle unit.

Two new cases have been added to the Survey gallery, Royal Scottish Museum, and the congestion that existed relieved. Progress has been made with the new exhibits of Mesozoic fossils that are now represented up to the Inferior Oolite inclusive.

C.—CHEMICAL DEPARTMENT

During the past year analyses of 23 rocks were made in the Survey laboratory. These included 11 iron ores for a Memoir on the British Sedimentary Iron Ores, and 6 fireclays for the Report on Refractory Materials; the latter report has also been arranged for publication. Of the remaining analysed rocks, one was a sample of Houston Marl, the other 5 being of igneous character.

Mineral separations of 2 samples of orthite were also made and the analyses are in progress.

Examination has been made of a method of cement-testing on samples supplied by the Building Research Board.

Numerous qualitative and partial analyses have been made for officers of the Survey.

D.—PHOTOGRAPHIC WORK

Mr. J. Rhodes during the year has taken 302 views of geological subjects, mainly in the counties of Dorset and Cumberland. Miscellaneous photographs to the number of 55 and 12 enlargements for the Museum have also been prepared.

The number of negatives now registered is as follows:—

English photographs	2,394
Photomicrographs	1,255
Miscellaneous	831
Total	4,480

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From the negatives of English photographs Mr. Rhodes has made 604 prints for incorporation in the Albums deposited for public reference in the London and Edinburgh Offices. Other prints of a duplicate and miscellaneous nature bring the total of prints made to 828.

The arrears in mounting of English photographs have been overtaken. The total number of prints and corresponding descriptive forms mounted during the year are 1,058 and 930 respectively.

In Scotland 28 views of geological interest were photographed in Argyllshire in the one-inch Sheets 51 (Coll) and 52 (Ardnamurchan).

The sale of prints and lantern slides to the public during the year was 369 slides, 70 prints and 2 enlargements.

III.—MUSEUM OF PRACTICAL GEOLOGY

During the year 1922 the total number of visitors to the Museum was 24,054; of these 20,107 visited the Museum on weekdays in the daytime and 2,020 in the evenings; the number of Sunday visitors was 1,927.

Fifty-nine demonstrations to schools and institutions have been given in the Museum throughout the year, the aggregate attendance being 1,246.

The work of expanding the economic collections has been continued. A case has been arranged to illustrate the uses of clay and a complete collection of British fireclays with their products is now on exhibition; the specimens are arranged topographically.

A special case illustrating the recent maps, memoirs and photographs issued by the Geological Survey, is now set up, and a new ¼-inch geological map of England has been mounted and is on exhibition.

The collection of building stones has been cleaned and relabelled and the stored collections in the basement have been put in order.

A new edition of the Museum Guide has been issued and the investigation of the Strathmore meteorite has been completed; a paper on this subject has been published in the Mineralogical Magazine.

In the Mineral Department the cleaning and registration of specimens in the older part of the collection has been continued, Wall-cases 16–22 having been dealt with.

A case has been arranged to illustrate the Bedded Iron Ores of North Wales.

Seventeen divisions of the Horseshoe Case have been cleaned and relined.

In continuation of the investigation of the English Iron Ores, specimens have been collected from a boring at Frodingham and from North Wales. Examination of the material is in progress and methods for the preparation of thin sections of these rocks are being investigated.

The total number of entries in the Mineral Inventory for the year is 554.

The inventory of the Ludlam Collection has been continued, the number of specimens dealt with being 1,671.

The number of members of the public and of officials of other Departments using the Library has shown no falling off.

The additions during the year comprise 172 volumes of independent works, 2,321 volumes and parts of serial publications, 534 maps, not including those bound in the foregoing, and 163 pamphlets.

The presentations to the Library include a number of volumes and pamphlets from the British Rainfall Organization, and from the executors of the late G. J. Hinde, and a further instalment from the library of the late H. B. Woodward.

Geological maps and memoirs to the number of 485, issued during the years 1914–1922, have been received from the Preuss. Geolog. Landesanstalt.

Particulars of the additions to the collection of geological photographs are given in the report on Photographic Work.

JOHN S. FLETT.
Director.

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List of Donations during the Year 1922

Balsillie, D., Esq., B.Sc.—Stalactite of melanterite.

Bosanquet, Prof. R.—A specimen of *Productus auritus* Phill., from the Carboniferous Limestone (D_2) at quarry on Rock Moor Farm, Alnwick.

Brelich, Henry, Esq., A.R.S.M., M.I.M.M.—Specimen of sillimanite from the Khasia Hills, Assam, Northern India.

British Buddhist Mission to Tibet (per G. Knight, Esq.).—A few rock specimens and quartz crystals, and an ammonite from Gyantse, Tibet.

Brown, G. F., Esq.—A specimen of *Micraster cortestudinarium* Goldf., from the zone of *M. cortestudinarium* of Haling Pit, South Croydon.

Chandler, R. H., Esq.—Two specimens of *Cyrena sp.*, from the Woolwich Beds of Shorne Wood, Kent.

Chester, H. W., Esq.—A specimen of oak from the surface peat of Sawtry Fen, 2 miles south of Holme Station, Great Northern Railway, Huntingdonshire.

Clinton, H. G., Esq.—Various minerals from U.S.A.

Collins, H. F., Esq.—A large and varied series of mineral specimens from Mexico, Spain, N. Wales, etc.

Crofton, Cecil F., Esq.—A garnet brooch, and a cross set with cairngorms.

Davis, A. G., Esq.—Three specimens of *Notamia sp.*, from nodule in lower part of London Clay at Norbiton Potteries, New Malden, Surrey.

Dixon, E. E. L., Esq., B.Sc., F.G.S.—100 large specimens showing fissuring of Carboniferous Limestone and entrance of Millstone Grit into fissures at unconformable junction.

Giffard, H. P. W., Esq.—(*See* H.M. Petroleum Department).

Goulborn, Henry, Esq.—Specimen of talc in a vein of verdite.

Graham, His Honour Judge, K.C.—An agate containing water, from South America.

Groves, J., Esq.—A series of 32 slides of *Charophyta* from the Lower Headon Beds of Hordle Cliff, Hampshire. Figured Reid and Groves, *Quart. Journ. Geol. Soc.*, vol. lxxvii, 1921, plates iv–vi.

Hall & Raine, Messrs.—A series of iron oxides used as pigments.

Harvey, Captain (per Dr. H. H. Thomas).—Radio-active material from mine dumps.

Hewetson, R. L., Esq.—A human bone stained with copper; also gold quartz stained with copper and nickel.

Hibbert, Major, D.S.O. (per A. Broughton Edge, Esq.).—A specimen of fibro-ferrite from the Scouriotissa Mine, Morphou, Cyprus.

Higgins, G. L., Esq.—Silicified wood from Egypt.

Kalgurli Gold Mines, Ltd., The.—A series of specimens of gold telluride ore, from Kalgurli, Australia.

Kay, Rev. H., F.G.S.—Two specimens of *Dadoxylon Kayi* Arber, from the Halesowen Sandstone in mineral railway cutting, Witley Colliery, Halesowen, Worcestershire; also specimens of amethyst, barytes, etc., from the Diorite Quarry, Dosthill, Warwickshire.

Kitson, A. E., Esq.—(*See* The Hon. Nana Ofori Atta).

Knight, G., Esq.—(*See* British Buddhist Mission to Tibet).

MacDougall, J., Esq.—A series of gold specimens and of gold-bearing rocks from South America and other localities.

McMahon, Lieut.-Col. Sir A. H., K.C.I.E., C.S.I., G.C.V.O.—A valuable series of rocks and rock sections forming part of the collection of the late General McMahon.

Murray, E. F. O., Esq.—Specimen of apatite with magnetite, from India.

Nana Ofori Atta, The Hon., C.B.E. (per A. E. Kitson, Esq.).—A collection of forty crystals of diamond, from the auriferous fluviatile gravels of the Birrim River, Abomoso, Eastern Akim, Gold Coast, Africa.

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NEAVERSON, E., ESQ.—A spine of echinoid and a specimen of *Pyrina sp.*, from the Cenomanian Limestone of Shenley Hill, Leighton Buzzard.

O'DRISCOLL, FLORENCE, ESQ.—A polished specimen of opal matrix, and a specimen of Famatina Ore.

PARKINSON, J., ESQ.—A series of rock specimens from the Priscilly Mountain, Pembrokeshire.

PETROLEUM DEPARTMENT, THE DIRECTOR H.M. (per H. P. W. GIFFARD) ESQ.).—A sample of crude petroleum from the D'Arcy Well Boring, Dalkeith, Mid-Lothian, N.B.

RAW, F., ESQ., B.Sc.—A series of specimens showing casts of footprints and other impressions, from the Enville Beds in boring at Slade Heath, near Four Ashes, Wolverhampton.

SCOTT, H. KILBURN, ESQ., M.INST.M.M., F.G.S.—A series of samples of iron ores from the Prince Henri Mine, Luxembourg.

SHANNON, W. G. ST. J., ESQ.—Forty-eight microsections and 23 rock specimens from Torquay.

SHEPPARD, T., ESQ., M.Sc., F.G.S.—A specimen of "snakestone" (Ammonite with carved "head") from Whitby.

SWAN, MESSRS. CHARLES, & COMPANY.—Three emerald doublets.

TATHAM, ATHOL, ESQ. (per SIR AUBREY STRAHAN, K.B.E., etc.).—Two specimens of limestone (Ordovician ?), from the Esthonian Oil Field.

THOMAS, F. A. W., ESQ. (MESSRS. WILKENS & DEVEREUX).—A specimen of descloizite, from Oliphantfontein, South-west Africa.

TABLE I

STATEMENT showing the NUMBER OF GEOLOGICAL MAPS and SECTIONS issued by the ORDNANCE SURVEY to AGENTS, etc., during the year ended 31st December, 1922.

Particulars.	United Kingdom.	England.	Scotland.	Total.
TWENTY-FIFTH-INCH TO THE MILE MAP OF THE BRITISH ISLES :—				
Colour-printed	544	—	—	544
QUARTER-INCH TO THE MILE MAPS :—				
Colour-printed	—	822	82	904
Uncoloured	—	—	—	—
ONE-INCH TO THE MILE MAPS :—				
Whole-sheets, Hand-coloured :—				
Solid	—	76	103	179
Drift	—	40	2	42
Colour-printed	—	—	168	168
Quarter-sheets, Hand-coloured :— (Old Series)				
Solid	—	557	—	557
Drift	—	141	—	141
Quarter-sheets, Hand-coloured :— (New Series)				
Solid	—	—	—	—
Drift	—	—	—	—
Colour-printed :—				
Solid	—	54	—	54
Drift	—	1,884	—	1,884
SIX-INCHES TO THE MILE (COUNTY) MAPS :—				
Whole-sheets, Hand-coloured	—	122	23	145
Uncoloured	—	2	—	2
Quarter-sheets, Hand-coloured	—	40	26	66
Uncoloured	—	458	393	851
Horizontal Sections	—	48	1	49
Vertical Sections	—	54	6	60
TOTALS	544	4,298	804	5,646

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1922

I.—INTRODUCTION

By J. S. FLETT, M.A., D.Sc., LL.D., F.R.S.

In the London district most of the area mapped has been to the north and north-east of London and consists of London Clay, Claygate Beds and Bagshot Sands. The superficial deposits of boulder clay, gravel and brick earth have been carefully studied and provide many problems of great interest and complexity. When the revision of the maps of the immediate neighbourhood of London is completed this unit may be transferred to the Aldershot district, which has especial claims for early revision. Water supply questions requiring geological treatment are very frequent in the south-east of England and require constant attention from Mr. Dewey and his staff. Both Mr. Dewey and Mr. Dines have been engaged for part of their time in preparing reports on metalliferous ores, such as those of tungsten, manganese and copper, which are now in the press.

In the Midlands district, of which Mr. Cantrill has charge, mapping has been carried on principally in Shropshire and Staffordshire, in the Birmingham, Wolverhampton and Wem Sheets. Small areas of Silurian and Coal Measures have been revised, including the important Stourbridge fireclay field and the Halesowen, Keele and Enville beds of the Wolverhampton district, which maintain the characters described in previous "Summaries of Progress." The greater part of the ground revised, however, consists of the New Red rocks, which conceal the Carboniferous over a large area. The Glacial drifts of these Midland Counties have many peculiarities, and additions have been made to our knowledge of northern types of erratics (possibly Irish) in the boulder-clays and the outlines of the lakes that covered extensive areas at the close of the Glacial period. In these lakes sands and gravels were deposited often in the form of kames, eskers and terraces. The special features of the post-Glacial history of the drainage and the abandoned stream courses have much interest to students of the local topography.

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In the Lancashire district, Mr. W. B. Wright and his staff have been much engaged in a study of the palæontological succession in the Millstone Grit and Lower Coal Measures along the lines indicated by Mr. Bisat, who has obtained a sequence of goniatite forms in the corresponding beds in Yorkshire. So far as yet tested this sequence holds also in North Lancashire and will serve to confirm or correct the deductions arrived at on stratigraphical considerations and field evidence.

The revision of this ground has generally established the accuracy of the original survey, but it has been possible to arrive at a more thorough knowledge of the succession of the beds and their lateral variations. Much mining information has accumulated since the ground was last mapped; additional coals are now known, and the structure of the area is being carefully investigated. At present mining in this district is not on an extensive scale. The complete detailed succession of the Lower Coal Measures has now been determined and the outcrops of the grit beds of the Millstone Grit are delineated on the revised maps. At present it is not clear how far the names applied to these grits in the various parts of the district are justified, the relations of the "Third Grit" in particular being somewhat doubtful. An interesting example of lateral variation is described at the horizon of the King Mine in the Middle Coal Measures; it is suggested that this is of the nature of a "wash-out."

In the Whitehaven Coalfield further progress has been made in reading the succession of the Carboniferous rocks, which has hitherto not been perfectly understood. The Hensingham Grit is now regarded as belonging to the Carboniferous Limestone Series and forms a valuable and easily recognised horizon. Consequently the thickness of strata ascribed to the Millstone Grit has been reduced. A noticeable feature of that group is the abundance of shales and the comparative scarcity of sandstone or grit. Its upward limit has not yet been clearly defined.

In the New Red rocks of this district the long standing uncertainty regarding the horizon of the "Upper Gypseous Series" has apparently been cleared up, as Mr. Smith and his staff have reached the conclusion that these beds are part of the Stanwix Shales.

Further evidence has been obtained regarding the classification of the Glacial and post-Glacial deposits of the Carlisle, Silloth and Gretna districts and the presence of two boulder clays and two sets of gravel deposits, previously established, is thoroughly confirmed. Eskers, kames and outwash-deltas are a marked feature of the gravel deposits, and are supposed to indicate the existence of large post-Glacial lakes, of which the shore-lines can be traced at elevations of 50, 75, 100, 140 and 200 feet.

A large area of northern Northumberland has now been revised and the one-inch and six-inch maps are being prepared for publication. In the Scremerston district there are considerable reserves of coals, mostly of an inferior quality, which may ultimately prove worth working. The original survey of part

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of this district proved very reliable, but greater accuracy can now be attained in the identification of the limestones and consequently in the interpretation of the structure of the ground, which is to a large extent covered by drift. Owing to the paucity of boring records it is necessary to rely to a large extent on very careful measurement and detailed investigation of natural sections, especially those of the coast-line, but the sequence as a whole is being gradually elucidated. At Shilbottle new information is being obtained regarding the strata associated with the valuable Shilbottle Coal, which has been famous as a house coal for many years. Investigation is now being carried on in the Upper Limestone group in the Howick area and in the valleys of the Coquet and the Font. During the autumn season a start was made with the revision of the Coal Measures in the neighbourhood of Newcastle.

Revision work in the coalfields of Scotland was continued in Ayrshire, Lanarkshire, and Clackmannan. In Ayrshire the ground surveyed was mostly near Sorn, Galston and Stewarton. The Lower Old Red Sandstone of the Sorn district is invaded by a granite mass which has produced extensive contact alteration. There is a conformable passage between the Upper Old Red Sandstone and the Carboniferous, but the volcanic series which occurs near the base of the Carboniferous is much thinner in Central Ayrshire than in North Ayrshire, and the Carboniferous limestones are thin and may rest directly on the Upper Old Red Sandstone.

The Muirkirk Coalfield shows an interesting and varied succession from the Upper Old Red Sandstone upward. At the base of the Carboniferous the Cementstone group is not everywhere present. The limestones and limestone coals are well developed and may be correlated with the sequence in the Ayrshire coalfield to the west and the Douglas Coalfield on the east.

The revision of the Alloa and Bannockburn coalfields is now nearly completed and the new six-inch maps are being prepared for publication.

Considerable progress has been made with the mapping of Tiree, which consists entirely of various types of Lewisian gneiss with a well-known ornamental marble. On the mainland the gneisses of Ardnamurchan are mostly of Moine types and are penetrated by numerous dykes. Further information has been collected regarding the Jurassic rocks of Ardnamurchan and the Cretaceous and Tertiary sediments of Morven.

We are now in a position to formulate conclusions regarding the volcanic structures which form the western peninsula of Ardnamurchan. They provide many analogies to those already known from Skye and Mull, and the concentric arrangement characteristic of certain volcanic areas is exceptionally well illustrated. Cone-sheets, ring-dykes and screens appear in considerable variety and the sequence of rocks from basic to acid is exceptionally complete.

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The great tract of Moine rocks that occupies the interior of Sutherlandshire presents comparatively little diversity and so far as mapped last year is mostly of familiar types. Newer Granites penetrate the gneisses and show resorption or contamination phenomena where they include basic rocks of igneous origin.

The officers in charge of the Palæontological, Petrographical and Chemical Departments have investigated problems arising from the work of their colleagues in the field. Mr. Pringle has acquired new data regarding the palæontology of the Jurassic rocks of Dorsetshire and has visited a number of borings. Mr. Chatwin has been engaged principally on Tertiary fossils from the London area and Dr. Lee furnishes notes on Carboniferous fossils from Scotland and the Jurassic sequence in Ardnamurchan. With the completion of the description of the Tertiary igneous rocks of Mull, Dr. Thomas is in a position to provide a brief synopsis of the magmatic types encountered in that series.

II.—FIELD WORK

(A)—ENGLAND AND WALES

1. London and South-Eastern District

Henry Dewey, District Geologist.

C. E. N. Bromehead, B.A., Senior Geologist.

H. G. Dines, A.R.S.M., A.M.I.C.E.
F. H. Edmunds, B.A. } Geologists.

In the London District mapping has been continued in Sheet 257 (Romford) and the southern part of Sheet 240 (Epping). Mr. Bromehead surveyed the northern part of the London area in Sheet 256 and the survey of this Sheet is complete.

Messrs. Dines and Edmunds carried on the examination of the area between the Lea valley and Brentwood. The principal results of this work are the separation of the Claygate Beds from the London Clay and the more precise differentiation of the superficial deposits. The modifications of the course of the Thames during the Pleistocene period, as indicated by the distribution of the terrace deposits, have been specially investigated by Mr. Dines.

The increased demands for water brought about by new building schemes and the curtailment of supply due to the prolonged drought have led to the sinking of numerous wells, often over 500 feet deep. Among the principal geological results is the proof that the greatest thickness of the Gault known in Kent occurs near Kemsing. A large yield of water has been obtained from the Upper Chalk between Cheam and Sutton where 65,000 gallons an hour are obtained from a 40-inch borehole. The Ashdown Sand has yielded a large supply to Hastings; this is specially interesting as that formation does not rank high among prolific water-bearing strata.

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Mr. H. J. Osborne White completed the manuscript of the memoir on "The Geology of the Country south and west of Shaftesbury," (Sheet 313), in the early part of the year and Messrs. Dines and Hollingworth finished the mapping of the superficial deposits and certain corrections of the Lower Cretaceous and Gault boundaries in that Sheet, preparatory to the issue of a colour-printed edition.

TERTIARY

Mr. Bromehead has surveyed a considerable area in the northern half of the North London Map (Sheet 256). The "solid" formations exposed at the surface are London Clay and Claygate Beds; the separation of the latter subdivision from the main mass of the London Clay makes the map more intelligible by bringing out the high ground and, to a certain extent, the geological structure of the area. Thus the outliers of the Claygate Beds at Stanmore, Elstree, Woodcock Hill, Arkley and Cock Fosters lie along the normal strike of the rocks, some twenty degrees north of east; while those of Highwood Hill, Totteridge and Mill Hill indicate a subsidiary synclinal axis at right angles to the strike. The topographical basin around Edgware, marked by the radial tributaries of the Silk stream, is shown by the semi-circular distribution of the outliers of the Claygate Beds to be also a structural basin. From the economic point of view, again, it is an advantage to have the loams of the Claygate Beds mapped separately from the stiff London Clay; brickpits have been worked in the Claygate Beds at Brockley Hill, Elstree, Arkley and Totteridge. Unfortunately no fossils have been obtained during the survey to show whether the Claygate Beds represent a palæontological horizon or merely a change in the character of the sediment, the loams of one area being contemporary with the clays of another situated nearer the centre of the London Basin.

From the position of the outcrops of the Claygate Beds the thickness of the London Clay proper can be ascertained at a number of points. At one or two of these the figure has been obtained directly from the record of a boring starting in the Claygate Beds; at the majority, however, it has been calculated by comparison of the levels of the Basement Bed in various borings near the boundary of the Claygate Beds. Along the strike the results show a slight thickening towards Hampstead from both directions:—Hanger Hill, Ealing, 300 feet; Willesden Green, 330 feet; Hampstead, 330 to 375 feet; Highgate, 350 feet; Chingford, 280 feet. In the direction of the dip there is a steady thickening towards the axis of the syncline, as the following figures show:—Stanmore, 200 feet; Harrow, 210 feet; Horsenden Hill, 248 feet; Hanger Hill, 300 feet.

Mr. Dines notes that in north-west Essex the Claygate Beds attain a thickness of 60 feet. They occur over nearly the whole area of Epping Forest, and are exposed in Hastings' brickyard at Pole Hill, Chingford, where 20 feet of alternating beds of sand

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and loam overlie the London Clay. The beds vary from four or five inches to upwards of a foot in thickness and enclose ferruginous concretions or boxstones in large numbers. Springs arise at the junction with the London Clay. Small outliers are seen at Pole Hill, Dog Kennel Hill and Havering Grange. In the country lying south of Chipping Ongar Mr. Edmunds observed the effect of rapid stream-erosion in these beds. It has produced narrow and deep valleys at the Coppice, N.E. of Kelvedon Hatch and near Lincolns, south of Coxtie Green.

The Bagshot Sand, as surveyed by Mr. Dines, forms a large outlier at High Beech and is exposed in front of the King's Oak Inn. At Loughton Camp there is another outlier; the beds worked for sand at Turpin's Cave are still exposed in the old pits. At Jack's Hill, north-west of the Wake Arms, another area of sandy loam may be of Bagshot Sand. There are several small pits in loam that is rather more of a clay than the normal Bagshot Sand, but its colour is similar to that of the High Beech outlier. This loam may belong to the base of the Bagshot Sand. If it were grouped with the Claygate Beds there would be an abnormal thickness of that formation at this locality.

PLEISTOCENE

Mr. Bromehead notes that the re-examination of the superficial deposits has not led to any new results of importance. The oldest member of the group, the Pebble Gravel of Stanmore and Bushey, Totteridge, Arkley and Barnet, is chiefly remarkable on account of the restricted distribution of the Lower Greensand chert. Both horny and spongy varieties of this rock are abundant in the gravel at Barnet and Totteridge; it appears to be derived from the southern or Wealden outcrop. At Stanmore and Arkley the chert is absent or exceedingly rare. Yet the gravels of Barnet and Arkley are parts of a continuous spread. The limit of the chert in these gravels has previously been noted by Mr. R. W. Pocock in the ground to the north; he traced it from Little Berkhampstead to Wrotham Park.[1] The other constituents of the gravel, Tertiary flint pebbles, flints and small quartz pebbles, are in no way affected by this dividing line, nor do the levels at which the beds occur show any change. These facts suggest that the chert was brought into the district from the south at some period anterior to the deposition of the gravels in which it is now found, and to the formation of the Thames valley; this period cannot have been earlier than that of the Barton Beds, in which Lower Greensand chert first makes its appearance in the Tertiary strata farther south.[2] The present limit of the chert in the gravels may be taken to indicate approximately the margin of an earlier chert-bearing deposit, of which the age between the above limits cannot be ascertained.

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, p. 33.

[2] 'Geology of Windsor and Chertsey' (*Mem. Geol. Surv.*), 1915, pp. 53, 55.

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The Glacial Gravels with Bunter pebbles and other constituents foreign to the Thames Basin are, in this area, easily distinguished from the earlier Pebble Gravel. They are found about the level of 300 feet, while the Pebble Gravel lies above 400, though in the district to the north, Mr. Pocock[1] finds that the Glacial Gravels and the Boulder Clay overlap the older deposit. The well-known Boulder Clay of Finchley has been mapped through Whetstone, about a mile farther north than is shown on the old map, but there are now no satisfactory exposures. The Boulder Clay and accompanying gravels enter the area shown on Sheet 256 between Botany Bay and the present Lea valley, following what probably represents the Lea valley of that period; the downward succession of the Glacial Gravel, Boyn, Taplow and Flood-plain terraces shows that the Lea has been constantly shifting its course to the east in the Enfield and Tottenham reach. Apparently the Boulder Clay did not override the high ground of Hampstead and Highgate; outlying patches of the gravels are found to the south-west of Finchley, bordering both sides of the Brent valley, but no Boulder Clay has been mapped there; probably a patch exists in Hendon village, but it is now impossible to trace its limits; that shown by Hicks[2] in his map of the area is undoubtedly too large.

The river-deposits of the Lea valley were mapped on the six-inch sheets by Mr. J. A. Howe twenty years ago. It is seldom possible to fix exactly the position of the slope which separates the Taplow terrace from the Flood-plain, as it is for the most part masked by the brickearth. Near Green Street, however, it is marked by a small outcrop of London Clay and near Edmonton it was revealed in excavations for a gravel-pit.[3]

Mr. Dines surveyed several areas of boulder-clay in north-west Essex. At Yardley Hill[4] there are three small patches. At Barn Hill, a little to the north, there is a capping of boulder-clay and much of the country between the two hills is covered with *remanié* drift. No boulder-clay has been recognised in the Lea valley south of Yardley Hill. It has been mapped at Woodredon, north of Theydon Bois, north-east of Loughton, and at Chigwell.

Glacial Gravels form the high ground between Woodford and Buckhurst Hill, smaller areas to the west and north, and also at Claybury north of the Asylum. At many localities glacial gravel underlies boulder-clay, but on the northern boundary at Dagnam Park similar gravel lies on boulder-clay. At Loughton cemetery a gravel of abnormal character is associated with boulder-clay and probably underlies it, but the boundaries are concealed. Grave sections vary, but generally show two feet of gravel resting on four feet of buff sandy brickearth, apparently

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[1] *Op. cit.*

[2] *Quart. Journ. Geol. Soc.*, vol. xlvii, 1891, pp. 575–584 and plate xxii.

[3] *See* S. H. Warren, *Proc. Geol. Assoc.*, vol. xxv, 1914, pp. 285, 286.

[4] P. G. Thomson, 'Notes on the occurrence of Chalky Boulder Clay at Chingford,' *Essex Nat.*, vol. xviii, 1914–1918, p. 2.

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stoneless, followed by red loamy sand containing, among other constituents, numerous large unworn or slightly rolled Chalk-flints. The deposit was seen to a depth of 6 feet. At 12 feet from the surface the deposit is locally cemented into a ferruginous "pan" four inches to a foot in thickness. Mr. P. G. Thomson found pebbles of the following rocks at this locality,[1]—basalt, Millstone Grit, Bunter sandstone and quartzite, crinoidal limestone and Rhaxella chert.

In the Roding valley some gravel hitherto classed as Glacial Gravel has been included with the terrace gravel of the Roding. The height of these deposits above the river and their general characteristics accord better with the terrace than with the glacial deposits. For instance the gravel at Chigwell, Chigwell Lane station, and part of the gravel south-east of Loughton and south of Theydon Mount have been so mapped. A patch of gravel near Claybury Asylum, previously classed as Valley Gravel, is now considered to be of glacial origin.

According to Mr. Edmunds, some gravel which seems to correspond to the 'Warley group' has been mapped on both sides of the road one mile north of Kelvedon Hatch. Glacial Gravel has been mapped at Langford bottom, 1½ miles south-west of Stanford Rivers, at Standon Massey and at Locksmith Wood, one mile south of Coxtie Green. Some gravels mapped as Glacial on the old map at Navestock Park and south of Stanford Rivers have been divided into river gravel and Glacial Gravel.

An interesting example of incised meanders has been described by Mr. Edmunds. To the north of Stanford Rivers a small stream flows over a deposit of brickearth into which it has cut a series of acute meanders to depths varying from six to eight feet. This brickearth, which may be contemporaneous with the Taplow brickearth, apparently filled a pre-existing valley. Some old excavations in a disused brickyard show that at a distance of 20 yards from the right bank of the stream the London Clay occurs about 3 feet from the surface. It also occurs on the left bank ten yards from the stream. The brickearth extends to the junction of the tributary with the Roding valley, where it spreads out on the right bank of the main valley immediately below the confluence.

2. Shropshire and Staffordshire District

T. C. Cantrill, B.Sc., District Geologist.
C. B. Wedd, B.A. } Senior Geologists.
R. W. Pocock, B.Sc. }
T. H. Whitehead, M.Sc., A.R.C.Sc. } Geologists.
T. Robertson, B.Sc. }

In Shropshire Mr. Pocock has completed the re-survey of the Wem Sheet (138), the area revised extending from Ellesmere on the west to Market Drayton on the east.

[1] 'On the occurrence of Rhaxella Chert in Epping Forest Gravels,' *Essex Nat.*, vol. xvii, 1912–1913, p. 258.

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In Staffordshire Mr. Whitehead has been occupied with the mapping of the extreme south-western portion of the South Staffordshire Coalfield and its borders as far west as Whittington Common and Churchill, in the Dudley Sheet (167), and southward into the adjacent Droitwich Sheet (182). In the Wolverhampton Sheet (153) Mr. Robertson has carried the re-survey of the neighbourhood of Wolverhampton westward as far as Shipley and Patshull, and has completed the portion of the South Staffordshire Coalfield lying between Wolverhampton and Bilston.

SILURIAN

Some small inliers of Silurian rocks fall within the area surveyed near Stourbridge by Mr. Whitehead. One of these is the well-known occurrence at the Hayes, Lye[1], where beds from the Lower Ludlow Shales to the Downton Castle Sandstones are exposed. These beds dip to the east, and are overlain on that side by the coarse basal conglomerate of the Middle Coal Measures. About 100 yards to the west, in a small brook, these basal conglomerates, here not so coarse, were found again, also with an easterly dip. It is clear, therefore, that the Silurian outcrop of the Hayes is terminated towards the west by a fault. In the brook referred to, the Coal Measures conglomerate rests upon hard, highly micaceous purple and green sandstones, and also, a few yards farther north, upon purple and green mottled clays. No fossils were found in these sandstones and clays; but from their lithological characters, and their position relatively to the Coal Measures conglomerate, it seems clear that they are of 'Red Downtonian' (or Ledbury Passage Bed) age. Red Downtonian rocks at this locality appear not to have been hitherto recorded.

Another small exposure of Silurian rocks occurs in Perrin's Lane, near Careless Green, Wollescote. Here Mr. W. King identified the Ludlow Bone Bed in a sewer-trench; but when the locality was visited during the survey, only the unfossiliferous lower portion of the Downton Castle Sandstones was exposed *in situ*. Some highly micaceous green sandstones and purple and green clays occur in Ludgbridge Brook, about 50 yards east of Spring Street. These dip north-westwards, at about 40°, under a coarse Coal Measures conglomerate, and should perhaps be referred to the Downtonian.

Another unrecorded exposure of Downtonian rocks occurs at Coalbournbrook, near Dennis Park, and 700 yards south-west of Brettell Lane Station. Here, underlying the coarse basal Coal Measures conglomerate, there are highly micaceous dark purple and pale green sandstones, dipping eastward at 55°. These sandstones rest on hard dark purple marls, which are

[1] J. B. Jukes, 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, pp. 107, 154; W. W. King and W. J. Lewis, 'The Uppermost Silurian and Old Red Sandstone of South Staffordshire,' *Geol. Mag.*, 1912, p. 439; W. W. King, 'The Plexography of South Staffordshire in Avonian Time,' *Trans. Inst. Min. Eng.*, vol. lxi, 1921, Figs. 1 and 2, p. 158.

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somewhat micaceous, and have pale green patches. About 50 yards west of this exposure a fragment of green coarse micaceous sandstone was dug up, very similar in appearance to certain of the sandstone beds in the Temeside Shales at Brewin's Bridge, Saltwells.

Fossils collected from the Silurian limestone outcrop at Park Hill (just south of Wolverhampton), in the area surveyed by Mr. Robertson, prove it to be Aymestry. By a mistake in colouring it is represented as Wenlock Limestone on the Old Series One-inch Sheet 62 S.W., though correctly described as Aymestry by Jukes.[1]

CARBONIFEROUS : COAL MEASURES

In the area between Wolverhampton and Bilston Mr. Robertson reports that little alteration has been made in the mapping. The Old Hill Marls are well exposed in the Phœnix clay-pit a short distance north of the Fighting Cocks, and the coals have been worked underneath them. The main fault that throws down the productive Coal Measures against the Keele and Enville Beds must, therefore, lie farther west, probably near the Dudley road.

At Wednesfield clear evidence of the intrusive nature of the dolerite on which the town is built is to be seen in a pit about 100 yards south of the canal bridge at the tramway terminus. Here the igneous rock is overlain by Coal Measures shales, which are baked for about a foot from the junction.

The sandstones of the Enville or Keele Beds, which form the conspicuous ridge on which the public buildings of Wolverhampton stand, can be seen only occasionally in excavations. It is certain, however, that a continuous band of higher Carboniferous rocks extends from Penn Common *viâ* Wolverhampton and Heath Town to Hilton Park.

Near Stourbridge, Middle Coal Measures have been found by Mr. Whitehead to crop out over an area averaging about a mile and a half broad between the Western Boundary Fault and the Hayes Fault. The Lye Station (G.W.R.) lies approximately in the middle of this area, which contains a large portion of the well-known Stourbridge fireclay field. The area includes the southern termination of the Netherton anticline, and another fold, of monoclinal form, of which the axis runs in a north-east and south-west direction in the neighbourhood of Peter's Hill, Amblecote. Between these two arches lies the basin of Hay Green and Hungary Hill. This area of Middle Coal Measures is terminated on the south by a fault, running a little north of east, near Wollescote Hall, which throws down the Halesowen Beds against them.

The Etruria (Old Hill) Marl crops out over the greater part of the area around Cradley, between the Hayes Fault on the west and Coombes Wood on the east.

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), Ed. 2, 1859, p. 148.

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Halesowen Sandstones, however, occupy Homer Hill and a smaller area at Overend, Cradley, being thrown down to this position by the Cradley Fault. The main outcrop of the Halesowen Beds comes in south of this, and their base can be traced from near Furnace Hill, Halesowen, by Belle Vale and Windmill Hill, to the Hayes Fault near Careless Green. West of this point the Halesowen Beds are cut off to the north by the Wollescote Hall Fault before mentioned.

The Halesowen Beds appear to include at least two fairly persistent coal-seams, of which the lower is that included in his 'Halesowen Coal and Clays' group by Mr. H. Kay.[1] The higher seam is exposed in the dingle immediately south of the old Wassel Grove shafts. In addition, impersistent seams, streaks, and pebbles of coal occur in several localities.

The Halesowen Beds pass gradually into the overlying Keele Beds. The highest beds of the former consist of grey clays, which, followed upwards, become mottled with red and purple until the latter colours predominate. It is in these purple clays that the little coals of Uffmoor Wood, referred to in the 'Summary of Progress for 1920,'[2] occur.

In the stream-course running from the north-east corner of Hagley Wood to Lutley Brook, traces of a Spirorbis limestone have been found in these clays. Similar clays are seen in Wollescote Dingle, west of Hodge Hill. The buff Halesowen Sandstones of Hodge Hill are abruptly truncated some 700 yards south-west of the summit, near where a public footpath crosses the dingle. In the dingle at this point red marls and purple and lavender sandstones, considered to represent the basal beds of the Keele group, dip at a steep angle to the north-west. It is clear that a fault throwing down to the west occurs here. This is believed to run towards Careless Green, near which it and the Hayes Fault, the Wollescote Hall Fault, and another fault running between Oldnall Colliery and Foxcote, all meet. Thus the Hayes 'Fault' proper, which is a down-throw or down-fold to the east, cannot be said to extend south of Careless Green, being here replaced by the Wollescote Dingle Fault, with a downthrow in the opposite direction.

South of Hagley Wood, and in Hagley Park, bands of sandstone and 'pellet-rock' occur, which become increasingly calcareous as they are followed upward. The higher beds, with their interbedded marls, are believed to represent the Calcareous Conglomerate Group of the Enville Beds (the 'Middle Permian').[3] In Hagley Park the highest of these beds contains small pebbles.

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[1] 'On the Halesowen Sandstone Series of the South Staffordshire Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, p. 442.

[2] *Mem. Geol. Surv.*, 1921, p. 14.

[3] W. W. King, 'The Permian Conglomerates of the Lower Severn Basin,' *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 111; *see also* T. H. Whitehead in 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, Appendix vii.

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These beds are followed upwards with apparent conformity by the well-known Clent Breccia, described by Mr W. King.[1] The well-bedded character of this deposit (noted by that author) is worthy of mention. Perhaps the best exposure is that afforded by the stream-section west of Great Farley Wood.

TRIAS

In the neighbourhood of Market Drayton Mr. Pocock finds that the soft red sandstones of the Lower Mottled division of the Bunter are exposed in the valley of the Tern, and are overlain by the Pebble Beds, which are here well developed.

The silicified wood found by Mr. Pocock at Hungryhatton[2] has been examined by Dr. Kidston, who refers it to *Dadoxylon kayi* Arber,[3] a Carboniferous species, and, so far as we know, as yet found in the Staffordian Series alone.

Further examination of the beds in which the wood occurs leaves little doubt that these are Bunter Pebble Beds, and we can only conclude that the fossil wood is derived. It does not seem possible, however, that the logs could have been drifted into their present position if they had already been silicified, as the maximum diameter of the associated pebbles is about one inch, while the logs measure six to nine inches in diameter and up to four feet in length. It is suggested that their silicification was subsequent to their deposition in the Pebble Beds.

The Bunter Beds near Market Drayton are bounded on the west by a continuation of the fault that forms the eastern limit of the Hawkstone area. To the west of this fault Keuper Marl is exposed at many points in the valley of the Tern and between Ternhill and Faulsgreen.

Near Ashford Grange the Keuper Marl is exposed on the east of a fault that brings in the Lias. On general considerations of structure, this fault has been continued to the south-west beneath the drift, to Middle and Great Ness.

No Rhaetic Beds have been found in place around the Lias outlier of Prees, as their outcrop is everywhere concealed by drift.

The base of the Keuper Marl on the western side of the synclinal basin cannot be drawn with certainty, as there the drift has a thickness of from 100 to 200 feet. An approximation has, however, been arrived at on the evidence of a boring at Welshampton, which, after penetrating 192 feet of drift, passed through 248 feet of red marl into red sandstone for 8 feet.

Mr. Robertson finds that on the west side of the Wolverhampton ridge there is a strip of Bunter Pebble Bed sandstones stretching from Upper Penn *via* Goldthorn Hill and Dunstall Park Station (on the Great Western Railway) to Bushbury Hill. This is roughly parallel to the belt of higher Carboniferous rocks between Penn Common and Hilton Park. The junction is imperfectly seen in a gravel-pit on the Colton Hills and appears to be an uncon-

[1] 'Clent Hills Breccia,' *Midland Naturalist*, vol. xvi, 1893, pp. 25–27.
[2] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 34.
[3] *Quart. Journ. Geol. Soc.*, vol. lxix 1913, p. 454.

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formity, but not necessarily a very marked one. This is probably the case at Bushbury also; but in the centre of Wolverhampton a fault separates the formations, and has been proved in excavations at the Market Buildings and elsewhere.

There is a wide stretch of fairly low ground underlain by Upper Mottled Sandstone between this Pebble Bed strip and the Tettenhall and Compton scarp. Just north of Dunstall Park a fault coursing north-west and south-east, with downthrow to the north, brings in Keuper sandstone, and small faulted outliers of the same formation are also to be seen at Dunstall Hill. To the south, Keuper sandstone appears again on the ridge connecting Upper Penn with Lower Penn. This sandstone, which is continuous with that which forms the Orton Hills, is cut off to the east by a fault.

The best exposures of the basement-beds of the Keuper in this area are to be found along the scarp that forms a marked feature from Tettenhall south-westwards by Compton, Perton and Great Moor to a short distance west of The Clive. The succession varies markedly from place to place, but the following typical sections show noteworthy points of resemblance :—

The Clive, Pattingham.	Perton, Wrottesley.	G.W.R. Locomotive Depot, Stafford Road, Wolverhampton.
Fine-bedded non-pebbly soft brown sandstone.	Coarse-grained pebbly brown sandstone.	False-bedded brown sandstone.
Coarse to medium-grained pebbly brown sandstone, 10–12 ft.	Coarse grit with pebbles up to 4 in. in length, 3½ ft. Calcareous pebbly grit with marl-fragments, 6 in.	Calcareous pebbly sandstone with angular marl-fragments, 6 in.–2 ft.
Micaceous purple marl with millet-seed quartz-grains, 2 ft. Fine-grained light reddish-brown sandstone with micaceous marly bands, 4 ft.	Purple sandy marl with millet-seed quartz-grains, 8–10 ft. Possibly a slight gap.	Marly sandstone passing laterally into marl. 2–3 ft.
Reddish-brown to green mottled calcareous marly sandstone with scattered millet-seed quartz-grains, 12 ft., passing downward. Fine-grained brown sandstone, 2–3 ft., passing downward.	Reddish-brown fine-grained calcareous sandstone with millet-seed quartz-grains, 4 ft., passing downward.	Dark reddish-brown sandstone, in some cases calcareous, 10–15 ft. Calcareous sandstone with many quartz-pebbles and marl-fragments, 1–2 ft.
Upper Mottled Sandstone.	Upper Mottled Sandstone.	Upper Mottled Sandstone.

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There are usually three fairly distinct stages in the transition. The Upper Mottled Sandstone passes upwards into a calcareous marly sandstone with millet-seed quartz-grains. This is succeeded in most sections by a definite marly band, which attains a thickness of 20 feet at Lower Penn. Above it comes a coarse pebbly calcareous grit with angular marl-fragments.

These basement-beds of the Keuper are succeeded by pebbly sandstones, which pass upwards through non-pebbly sandstones into finely-bedded marly sandstones. These in turn pass up within a short distance into the Keuper Marl by the intercalation of marly bands. This is well seen at Nurton Hill, Pattingham. The transition is too rapid to make possible the mapping of an intermediate group of Waterstones; nor has any break in the succession been detected.

Near Stourbridge, in the area south and west of the South Staffordshire Coalfield surveyed by Mr. Whitehead, the Lower Mottled Sandstone occurs only to the west of the Bunter Pebble Bed escarpment that forms the line of hills including the Wollaston Ridge and Bunker's Hill. The outcrop of the Lower Mottled Sandstone is bounded on the west by the Stapenhill Fault, which throws down against it the Upper Mottled Sandstone, and, in one place, about a mile west of Wollaston, a small outlier of the basement beds of the Keuper. The Lower Mottled Sandstone is dug for building-sand near the point where the Bridgnorth road crosses the Pebble Bed escarpment of Wollaston, and here shows its false bedding in a striking manner. At this place also the irregular and pockety character of the base of the Pebble Beds is well exhibited. Along this escarpment generally the Bunter Pebble Beds are well consolidated, and include bands of hard conglomerate with a calcareous cement.

On the south and south-west borders of the Clent Hills, on the other hand, where the Pebble Beds rest directly upon the Clent Breccia, the former are usually imperfectly consolidated. The discordance between the Pebble Beds and the Breccia is marked, and in Hagley Park the former appear to overstep the Breccia altogether and to rest on the beds below it.

The Upper Mottled Sandstone outcrop occupies a strip of country extending south-westwards from Stourbridge to Churchill and Blakedown. Smaller patches emerge against the Western Boundary Fault at Old Swinford, Hagley, and near Hollies Hill, Belbroughton. This formation is dug for moulding-sand in the Stourbridge district. The main outcrop of the Lower Keuper Sandstone extends from Stourbridge, where it meets the Western Boundary Fault just south of the River Stour, southwards to Belbroughton and beyond. The basal beds consist usually of 2 or 3 feet of dark-red or chocolate-coloured marl, followed by a calcareous breccia with pellets of marl and, in places, pebbles (' catbrain '). Both the marl and the catbrain are seen in the faulted outlier west of Wollaston referred to above.

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JURASSIC

The southern part of the outlier of Lias at Prees has been mapped by Mr. Pocock. As the Lower Lias is almost entirely concealed by drift, its base has been drawn solely on consideration of dip and assumed thickness. The record of a boring near Wem Station appears to indicate a thickness of more than 80 feet of Lias; but as this was a percussion boring and no samples were obtainable, we cannot place much confidence in the record. If this is Lias it may possibly be brought in by faulting.

The top of the Lower Lias is exposed near the base of Prees Hill. Middle Lias forms the hill itself, and is about 100 feet in thickness. The small exposure of Lias against the fault near Ashford Grange is also thought to belong to the Middle division. Upper Lias appears to be absent at Prees; an exposure at the highest point of the hill yielded fossils characteristic of the upper beds of the Middle Lias.

GLACIAL AND POST-GLACIAL

In the area mapped by Mr. Pocock the drift attains a thickness approaching 200 feet near Ellesmere. It is of moundy morainic type, with large meres and peat-mosses in the hollows. The most important of the peat-mosses is Whixall Moss, where there are extensive diggings for peat.

Between Whixall Moss and Edstaston, stiff boulder-clay forms the surface, and the thickness of the drift is not known.

Over Prees Higher Heath and round Prees Hill there is a wide area of sand and gravel with a fairly flat surface rising to nearly 300 feet above Ordnance Datum. These deposits can be followed eastwards in a wide belt to Bletchley, where they are cut through by a north-and-south valley, on the east of which they extend to Little Drayton. The sands are believed to have been deposited under lacustrine conditions at the close of the Glacial period, there being evidence of a shore-line, at a level slightly below the 300-foot contour, that can be traced at intervals over a large part of the area of the Wem Sheet. The lake described by Mr. Dixon in the Newport district[1] is, therefore, thought by Mr. Pocock to have covered a large part of the North Shropshire plain.

An interesting case of river-capture has been brought out by the mapping of the valley of the River Tern. A broad north-and-south valley enters the area of the Wem Sheet (138) near Longslow. The river Duckow, a small stream, enters this valley on the west near Longford and flows northward to join the Weaver. About a mile and a half farther south the Bailey Brook enters the valley on the west and flows southward to join the Tern. In the broad alluvial flat between these two streams, at a height of about 220 feet above O.D., is the watershed

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 17; and for 1920' (1921), pp. 19, 20.

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between the Mersey drainage to the north and the Severn drainage to the south. There is little doubt that this valley held the original River Tern, its head-waters having been captured subsequently by the Weaver. The present Tern, which flows past Market Drayton, joins the main valley on the east near Ternhill.

In the coalfield between Wolverhampton and Bilston Mr. Robertson finds that there is not a great deal of drift. The drift-filled river-channel described by Dr. Gibson[1] has been traced from Moxley northwards as far as the canal between Wolverhampton and Willenhall; but beyond that point there is no information regarding it. It maintains its comparatively narrow, steep-sided character throughout. North of the road between Wolverhampton and Willenhall most of the ground is covered with stony clay drift. The Wednesfield sill, however, is free from drift in the northern portion of the town, and the Pebble Beds of Bushbury Hill rise out of lower drift-covered ground. A sheet of clayey drift covers most of the ground on which the town of Wolverhampton is built, except the top of the ridge that extends from Goldthorn Hill to Oxley. Oxley Manor estate is covered with more gravelly material, and so is the area between Merryhill and the Penn ridge. A tongue of drift, in part clayey, in part sandy and gravelly, extends round the west end of this ridge by Dimmingsdale towards the Smestow Brook valley at Trysull. Farther west, as far as Patshull and Rudge, the country is practically drift-free. A few small patches of gravel occur on the higher ground, similar to those found by Dr. Sherlock and Mr. Dewey in the ground to the north.[2]

Ice-borne boulders of all sizes are to be found in the Wolverhampton area. They are seen most commonly on the higher drift-free ground; but this is probably due to the fact that on the lower ground they are more easily concealed by surface-deposits and do not stand the same chance of having the drift around them washed away. The frequency with which large boulders are found in excavations in the clay supports this view. Nevertheless, there is a fortuitous concentration of boulders in some places. A small area to the north-west of Bradmore has yielded a great number of erratics, many larger than two feet cubes, of both Scottish and Lake District granites and of Welsh volcanic rocks. Mr. Dewey[3] noted the occurrence of similar boulders in the sand-pits between Compton and Lower Penn. At the north-west end of Abbot's Castle Hill, along the back of the scarp, large boulders of Criffel granite are exceedingly numerous. Erratics are not common along the Keuper Sandstone scarp between Shipley, Rudge, and Patshull High Park. At many of the farms, especially in the neighbourhood of Trescott, boulders have been collected from the surrounding land

[1] 'Summary of Progress for 1912' (*Mem. Geol. Surv.*), 1913, p. 31.
[2] 'Summary of Progress for 1915' (*Mem. Geol. Surv.*), 1916, p. 17.
[3] 'Summary of Progress for 1915' (*Mem. Geol. Surv.*), 1916, p. 17.

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and placed around or near the farm buildings, frequently to form walls.

An examination by Dr. Thomas in 1912 of certain specimens collected by Dr. Codd of Wolverhampton from the neighbourhood of Barnhurst and Palmer's Cross (between Wolverhampton and Codsall) showed the presence of granites from Criffel, Dalbeattie, and Eskdale, of granophyre from Ennerdale, and of Welsh volcanic rocks. Around Wolverhampton itself both Welsh and northern erratics occur, but the latter appear to predominate greatly. South-west of the town also, in the Smestow valley, the greater number of erratics appear to be northern ones, and amongst these by far the most common is the Criffel granite. The following list gives the types of erratics from distant sources, with, where possible, their derivations.[1] The more abundant are placed first :—

Northern.	Welsh.
Criffel granite.	Arenig lavas and ashes.
Ennerdale granophyre.	Grits.
Dalbeattie granite.	Trachyte.
Eskdale granite.	Keratophyre.
Lake District volcanic rocks.	Diabase.
Analcite basalt, S.W. Scotland.	Dolomitised Carboniferous limestone.
? Troctolite.	
Rhaetic limestone.	
Liassic limestone.	
Chalk flints.	

The Humber-Severn watershed passes through the town of Wolverhampton, and at Aldersley, north of Tettenhall, there is a well-defined gap (Fig. 1). It has steep sides and is about 100 yards broad at the bottom. In the later phases of the Glacial period this must have been the channel by which great quantities both of water and of rock-material passed into the head of the Smestow valley, and indications of what happened at that time are to be seen lower down the valley. The position of the gap itself is probably due to a fault that courses along the north side of Dunstall Park and brings Keuper Sandstone on the north against Upper Mottled Sandstone on the south. The soft Upper Mottled Sandstone made it more easy for denudation to produce a channel at Aldersley than would have been the case in the Keuper Sandstone to the west or in the Pebble Bed sandstones to the east.

The low Upper Mottled Sandstone country south of the gap is mainly covered with drift, chiefly clayey in character. It becomes more sandy, however, as the Penn ridge is approached, and on the north side of this ridge there are banks and mounds of gravel and sand. The Smestow Brook skirts this drift-covered area

[1] *See* F. W. Martin, *Proc. Birmingham Phil. Soc.*, 1888, pp. 93–118, and 1889, pp. 85–113; also W. J. Harrison in 'The Geology of the Birmingham District,' *Proc. Geol. Assoc.*, vol. xv, 1898, pp. 400–408.

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on the west, running parallel to the Tettenhall–Compton scarp as far as Wightwick, and then rounding the western end of the Penn ridge. This ridge appears to have acted as a barrier against

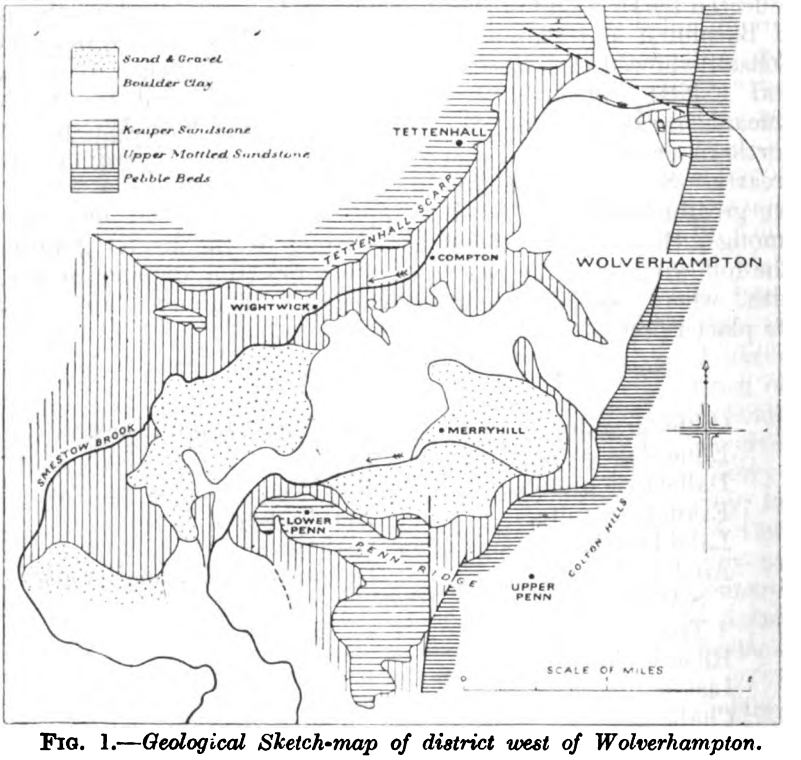

FIG. 1.—*Geological Sketch-map of district west of Wolverhampton.*

which much sand and gravel was banked. The water of the main sub-glacial, and afterwards of the late-glacial, drainage, hemmed in on the south by this ridge, on the east by the Wolverhampton-Penn ridge, and on the north-west by the Tettenhall scarp, flowed out westwards *via* Trescott and thence south to Seisdon, in the course at present occupied by the Smestow Brook. An interesting relic of the old, probably sub-glacial, drainage is to be found in the sand-pits south-west of Compton, where channels filled with sand and gravel run parallel to the main stream-channel at various heights above the present stream-bed, as noted by Mr. Dewey.[1]

Where seen in cross-section the best examples of these channels show a distinct deepening on the lower side, and are of such a shape as to postulate either marginal or sub-glacial streams.

Mr. Dewey also describes the beds that were exposed in the railway-cuttings between Tettenhall and Lower Penn and the esker-like ridges, near Langley Farm, that mark the course of the drainage round the end of the ridge from the *cul-de-sac* between Merryhill and Penn. The moundy character of this dead-end makes it probable that it has been little disturbed since, towards

[1] 'Summary of Progress for 1915' (*Mem. Geol. Surv.*), 1916, p. 17.

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the end of the Glacial period, a mass of ice was left in it and gradually melted away *in situ*.

In a sand-pit just north of Langley Farm a great variety of erratics was found, including many Liassic rocks. Specimens were obtained that can with confidence be referred to the Rhaetic and to the Lower Lias. Flints with shell-casts are also present, and a Pleistocene *Turritella* was found, along with other shell-fragments. It is possible that the Rhaetic and Lower Lias erratics may have been derived from beds that occur at Prees, in Shropshire, though not now exposed; but the presence of Cretaceous rocks makes it advisable to assume their derivation from some area in which all the rock-types are present, *e.g.*, the north of Ireland.

In the area about Stourbridge and Churchill, Mr. Whitehead found numerous patches of gravelly and sandy drift. One of the most interesting of these is the deposit of pebbly sand and loam occupying a terrace-like feature on the north side of the River Stour at Amblecote, about 30 feet above the river. In this deposit mammalian remains (preserved in the Stourbridge Public Library) were found at Mills Meadow Amblecote.[1]

What appears to be a portion of the same terrace-like deposit lies south of the River Stour, near Prestwood. It is here some 10 feet lower than at Amblecote, but at about the same height above river-level. The sand and gravel at canal-level, near Bell's Mill, referred to in the 'Summary of Progress for 1920,'[2] is probably also part of this deposit.

In Norton Covert some sand-pits afford a good exposure in gravel and in laminated sand with lenticles of clay and loam.

The gravels contain many erratics, amongst which were recognised Ennerdale granophyre, ashes and rhyolites of North Welsh type, Rowley basalt, and a fossiliferous fragment containing *Glyptocrinus sp.*, *Orthis retrorsistria*, and *O. vespertilio*. For this fragment Mr. J. Pringle suggests a derivation from the Teirw Beds[3] of the Glyn-Ceiriog district (Denbighshire).

The beds of Norton Covert are very much like those forming the 'Kingswinford Esker'[4], and may well have had a similar origin. At the road east of Norton Covert the base of the drift is about 320 feet above O.D.; but, followed in a south-eastward direction, it rises steadily until on the high ground north of The Birches it reaches about 450 feet. It is likely, however, that the higher ground is covered by a drift deposit of separate origin from that

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[1] W. S. Boulton, 'Mammalian Remains in the Glacial Gravels at Stourbridge,' *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, 1916–17, p. 107.

[2] *Mem. Geol. Surv.*, 1921, p. 22.

[3] *See* T. Groom and P. Lake, 'The Bala and Llandovery Rocks of Glyn Ceiriog (North Wales),' *Quart. Journ. Geol. Soc.*, vol. lxiv, 1908, p. 551, and L. J. Wills and B. Smith, 'The Lower Palæozoic Rocks of the Llangollen District,' *Ibid.*, vol. lxxviii, 1922, p. 179.

[4] W. S. Boulton, 'An Esker near Kingswinford, South Staffordshire,' *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, 1916–17, p. 25, and 'Summary of Progress for 1920' (*Mem. Geol. Surv.*), 1921, p. 21.

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of Norton Covert, but it is impossible to draw a boundary between them on the map.

Farther south, about Stakenbridge, Churchill, and Blakedown, there are several patches of sand and gravel, and much of the intervening ground is covered by thin ill-defined spreads of pebbles and pebbly sand, probably representing *remanié* or downwashed drift. The patches of sand and gravel appear not to lie on a plane surface, though there is a gradual, but irregular, fall in their level from north to south. West and south-west of Blakedown the drift forms two well-marked banks, one at about 300 feet and the other at about 240 feet, separated by a flat shelf-like feature. On Barnett Hill (Sheet 182), however, the base of the drift sand and gravel lies at about 360 feet. The Stour valley above Stourbridge is free from drift, as is also the country to the south, including the Clent Hills west and north-west of Romsley Hill, and most of the ground around Hagley, Holy Cross and Broom. At Madley Heath (Sheets 182 and 183), a ridge about 1½ miles long, topped by drift gravel, trends north-east and south-west from a point about 500 yards south of Dayhouse Bank. On and about this ridge numerous erratics occur. Amongst these were found ashes, rhyolites, and slates of North Welsh type. In addition, boulders and fragments of a cream-coloured quartzose sandstone are rather common. In a fossiliferous fragment of this rock Mr. Pringle has identified *Spirifer bisulcatus* and *Pugnax pleurodon*. He suggests that the rock is derived from the Cefn-y-fedw Sandstone ('Millstone Grit') of North Wales.[1]

Near the village of Broom there is a deposit consisting largely of breccia-fragments, with an admixture of Bunter pebbles, in a sandy matrix. This 'breccia drift,' which seems nowhere to be more than 3 feet thick, is dug for gravel near Field House, building-sand being obtained from the same pit from the Keuper Sandstone beneath. The surface of the ground occupied by this deposit is nearly flat, and falls from a little over 400 feet to a little over 300 feet in about a mile from east to west. On the south the eastern portion of the deposit extends to the foot of a ridge formed by Keuper sandstone and conglomerates, whilst farther west it reaches to the edge of an incipient drainage-channel that runs down to the brook in Broom village. On the north the deposit is bounded by the stream that emerges from the Clatterbach valley, between Clent and Walton Hills. From Field House downwards this stream is markedly entrenched, and the 'breccia drift' extends to the upper edge of the bank formed by the entrenchment. On the north side of the stream there is in one place a flat terrace-like feature, corresponding in level with that on which the 'breccia drift' rests, but upon which this deposit was not found. A small patch of the deposit was, however, found on the north side of the stream near where it crosses the Hagley-Worcester road. It is here at 297 feet, which is lower than any part of the main spread.

[1] *See* 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, p. 10.

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The accumulation of this ' breccia drift ' deposit evidently took place when all the main topographical features of the district had attained their present form, but apparently before the entrenchment of the local stream-courses. The connection of the deposit with the Clatterbach valley seems clear, and it may well have originated as an outwash from that valley at a time when a greater annual rainfall than obtains at the present day produced a more vigorous stream-action amongst the Clent Hills.

Similar deposits were found at Lower Clent, at from 450 to 500 feet, and at Pedmore, at about 380 feet. That at Pedmore is as much as 5 feet thick in one place, and contains a considerable admixture of clayey material in the matrix. Traces of similar material were found here and there south of Holy Cross.

The spread near Broom is probably the oldest, and may perhaps be of early post-Glacial date; but in other places the material seems to graduate into the modern talus from the Clent Hills, so that it may have been in course of formation, with diminishing vigour, from early post-Glacial to recent times.

It is probable that the spread of red marl ' wash,' which in the neighbourhood of Hagley Wood and Hayley Green is so thick, and so completely masks the subsoil that it has been mistaken for ' Permian ' or Keele Beds *in situ*, had an origin analogous to that of the ' breccia drift ' above described.

3. Lancashire District

Headquarters : Manchester

W. B. Wright, M.I.M.E., District Geologist.
R. L. Sherlock, D.Sc., A.R.C.Sc., Senior Geologist.
D. A. Wray, M.Sc.
W. Lloyd, B.Sc.
F. Marsden, M.Sc.
L. H. Tonks, M.Sc.
} Geologists.

The re-mapping of one-inch Sheet New Series 76 was continued. Mr. Wright was largely occupied in the correlation of the grits and marine bands, and in examination of bore-holes, but surveyed some ground to the north of Bolton. Dr. Sherlock continued mapping in the Accrington area, and Messrs. Wray and Lloyd carried on their work between Burnley and Rochdale. Mr. Tonks surveyed for a short time to the west of Burnley, and Mr. Marsden was occupied in the neighbourhood of Blackburn.

Coal Measures and Millstone Grit of the Rossendale District

Considerable success has attended an attempt at zonal subdivision of the Lower Coal Measures, the Millstone Grit Series and the beds beneath the Kinderscout Grit along the lines indicated by Mr. W. S. Bisat at the Hull Meeting of the British Association in 1922, and the succession of goniatite forms

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established in Yorkshire has been found fully developed throughout the Rossendale anticline. Mr. Bisat has greatly facilitated this work by unreservedly placing at the service of the Lancashire unit his unpublished knowledge of the Yorkshire succession, and, as the publication of his results is pending, a detailed account of the palæontology would be premature in view of the fact that many of the species to which reference would have to be made are as yet undescribed. In the better exposed portions of the ground the palæontological succession has been found to hold without appreciable change in spite of considerable lithological variations, and the constancy of its development is such as to ensure confidence in its application to the interpretation of areas which are badly exposed or much complicated by faulting.

Through the courtesy of Mr. Lomax, microscopist to the Lancashire and Cheshire Coal Research Association, who has allowed a collection to be made from the bullion-material obtained by him from the roof of the Upper Foot Coal, it has been possible to make a thorough examination of the relations of the three forms of Gastrioceras found in this bed. The results arrived at confirm and to some extent amplify the observation of Haug[1] that these forms pass one into the other. The numerous specimens obtained were sorted into series of approximately equal size, and in each series a perfect gradation of form was proved from *Gastrioceras coronatum*, Foord and Crick, on the one hand, through *G. listeri* Auctt. to *G. carbonarium* v. Buch on the other. From a diameter of 15 mm. upwards *G. carbonarium* is the dominant form, while among the smaller sizes it is *G. listeri* that bulks largest. The proportion of *G. coronatum* is never great, but increases with decrease of size. The largest true *coronatum* observed was 23 mm. diameter, but there is some approach to the form up to 30 mm.

On breaking back a number of suitably weathered specimens it was found that *G. carbonarium* passes through a *listeri* stage in its early whorls and in its very earliest approximates to *coronatum*,[2] while *G. listeri* has an early *coronatum* stage. The young stage of *G. coronatum* itself is an extreme form of that species, with an umbilicus almost equal in diameter to the shell, a marked crown of tubercles and an extremely low ventral arch.

An ontogeny of this nature might be regarded as indicating that the ancestor of the group was of the *coronatum* type, and that on lower horizons this form might be dominant. Unfortunately the state of preservation of the goniatites in the marine bands immediately below the bullion-bed has hitherto prevented any accurate investigation of this question. The band at the base of the Lower Coal Measures shows only mere ghosts of some form of *Gastrioceras*, while that between the Rough Rock and the Hasling-

[1] E. Haug, 'Études sur les Goniatites,' *Mémoires de la Société géologique de France*, No. 18, 1898, p. 103.

[2] This relation is indicated by Foord and Buck in the figure on p. 230 of the 'Catalogue of the Fossil Cephalopoda in the British Museum, Part III,' 1897.

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den Flags, while it yields numerous large crushed internal casts of highly tuberculated and widely umbilicated forms suggestive of *listeri* and *coronatum*, has afforded up to the present no specimen with the ornament well enough preserved to make a comparison possible on any other lines than that of general form. Moreover, other undoubtedly distinct species of *Gastrioceras* are found in this bed, so that as yet there is incomplete evidence as to the ancestry of these forms.

BOLTON AREA

Middle Coal Measures were found here by Mr. Wright considerably to the north of their supposed limit, being let down between two north-west faults in the neighbourhood of Bradshaw and Eagley, where they are exposed in the stream sections. A corresponding area of Lower Coal Measures was proved between the same faults extending up the Eagley Brook beyond Dunscar, the Rough Rock crossing the valley above Egerton, and being well exposed in Delph Brook and the lower part of Longworth Clough. The Haslingden Flags are poorly developed in this district and no longer afford a clue to the interpretation of the ground, but at the head of Longworth Clough near Belmont some beds were discovered which from their fauna must be a short distance above the Third Grit. It is probable, therefore, that the coarse pebbly grit exposed in Belmont may be the Third Grit and not, as its lithological character might lead one to suppose, the Kinderscout.

ACCRINGTON AREA

Between Blackburn and Accrington a wide and much faulted trough of Lower Coal Measures is bounded on the south by a large fault bringing up Millstone Grit, and on the north by a sharp fold ranging south-west to north-east and bringing up the Millstone Grit at high dips.

Millstone Grit.—In this area, brought up by the sharp fold mentioned above, between Blackburn and Wilpshire to the west, and Rishton and Great Harwood on the east, the First Grit or Rough Rock is notable for the poor development of the part overlying the Sandrock Coal. Near Rishton this part is represented by about four feet of sandstone. The Second Grit (Haslingden Flags) is well developed west of Rishton and has been extensively quarried at Cunliffe and Close Brow quarries. The base of the rock is a massive sandstone, used for setts.

Below the Haslingden Flags is about 25 feet of greenish concretionary mudstone, which passes down into black shale with ironstone bands; this contains a marine band. In the stream bed towards the north-east of the Close Brow quarry is seen a thin coal with a 3-foot fireclay resting on more shale and this on grit. The Harper Clough quarry then takes up the succession. At the entrance to the quarry a coal-seam crosses, and below it is soft grit, which passes down through well-bedded sandstones into shale containing a marine band. A few feet below

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the band is a 7-foot sandstone with shaly flags below. Then comes a six-inch coal with about 4 feet of fireclay beneath, and about 11 feet of strata showing a transition to flagstones. Not many yards behind the quarry are crags of grit with some pebbles, the commencement of a series of grits, sandstones, and shales, extending downwards to the top of the Pendleside Series.

Lower Coal Measures.—It has been found that, between Accrington and Blackburn, and from Haslingden to Great Harwood, the Lower Coal Measures undergo but small variations. They have been mapped in considerable detail, and the various coal-seams, sandstones, and shales are shown separately on the six-inch maps. As most of the area is buried under drift and much is also built over, it is necessary in many places to rely upon information obtained from records of borings. Fortunately in the Accrington area these are numerous, and we are greatly indebted to the colliery companies and to Mr. J. Spencer, F.G.S., for the details.

In the Accrington area the general succession of the Lower Coal Measures is as follows. Below the Arley Mine there is :—

	Thickness. Feet.	Total. Feet.
Fireclay	5	5
Shale	44	49
Sandstone	37	86
Shale	104	190
Sandstone (Hambledon Scout or Coppice—Old Lawrence of Burnley).	104	294
Mudstone (Accrington mudstone)	100	394
Shale, black	25	419
Sandstone	52	471
Shale, black	112	583
Pasture Mine, to	3	586
Fireclay	2	588
Sandstone (Flag and Slate Rock or Crutchman Sandstone).	60	648
Shale, black (Book-leaf Shale)	75–90	723–738
Cannel Coal, to	1	724–739
Fireclay	4	728–743
Sandstone (Icconhurst Rock)	30	758–773
Upper Mountain Mine (40 yards Coal, Old Robin, or Yard Mine).	2¼	760–775
Fireclay	1	761–776
Sandstone and grit (Warmden Rock)	42	803–818
Inch Mine or Fireclay Clay	1½ ins.	
Fireclay	2½	805–820
Shale, black (Dewhurst Shale)	54	859–874
Upper Foot or Bullion Mine	9 ins.	860–875
Fireclay	9 ins.	861–876
Sandstone (Great Arc or Bottom Rock)	27	888–903
Shale	27	915–930
Lower Mountain Mine or Gannister Coal	2½	917–932
Gannister and Fireclay	3½	921–936
Devil's Den Coal, very local		
Fireclay	3	924–939
Shale	25	949–964
Lower Foot Coal	9 ins.	950–965
Fireclay	2	952–967

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	Thickness. Feet.	Total. Feet.
Shale	75	1027–1042
Bassey, or Salts Mine, or Shale Bed Coal	2	1029–1044
Fireclay	1	1030–1045
Sandstone (Woodhead Hill)	63	1093–1108
Shale	65	1158–1173
Ten-inch Coal	10 ins.	1159–1174
Fireclay	4	1163–1178
Shale	6	1169–1184

Of these divisions the four main sandstones can generally be recognised by their lithological characters. The Hambledon Scout Rock is a flagstone closely resembling the Haslingden Flags (2nd Millstone Grit) and, like that rock, succeeds a greenish mudstone. The Crutchman Rock is typically highly micaceous and has been extensively worked for flags and for roofing houses. The Warmden Rock, though in part flagstone, is frequently a grit, and could be mistaken for Millstone Grit. The Woodhead Hill Rock is a typical buff Coal Measures sandstone. All are current bedded.

The Accrington Mudstone is the raw material of an important brickmaking industry. The bricks made are of first-rate quality and are of a bright red colour.

Of the coals, only the Lower and Upper Mountain Mines are worked. The Upper Foot is well known as the source of the famous fossiliferous bullions so well known to palæobotanists. Below the coal there are coal balls, which contain plants still showing the microscopical structure, while above the coal the bullions contain goniatites and other marine fossils.

The area is traversed by numerous faults, and while the majority of them are normal, some have a reversed throw.

Towards the north-west the Lower Measures are brought up by the monoclinal fold referred to above, and rest at angles of from 45 to 50 degrees. It is in this region that the strata below the Lower Mountain Mine are best seen.

Middle Coal Measures.—In the Calder valley the lower part of the Middle Coal Measures exists under drift in a shallow syncline. The Arley Mine has been worked out in the area examined, *i.e.*, north of Hapton and Clayton-le-Moors.

Glacial.—The separation of Glacial Sand and Gravel from Boulder Clay offers considerable difficulties. The greater part of Great Harwood is built on sand and gravel. In the quarries at Rishton terminal curvature is well shown and proves that the ice came from a northerly direction. Striæ have not been found.

BURNLEY-TODMORDEN-ROCHDALE AREA

The area surveyed by Messrs. D. A. Wray and W. Lloyd comprises a belt of Coal Measures and Millstone Grit several miles wide, extending from Burnley through Todmorden to Rochdale. The ground is chiefly moorland, deeply cut by the Cliviger and Walsden gorges; and though for the most part bare and sparsely

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inhabited, the moorland, as a gathering ground for several important water supply schemes, is well worthy of economic mention. In former times the mining of several coal-seams centred an extensive industry on some of the moors, especially in the south, but the getting of coal is now confined to more or less deep workings, chiefly around the towns of Burnley and Rochdale.

The whole area is bounded on the east by the axis of the Pennine anticline; but whereas the district from Todmorden to Rochdale is in a broad sense a N.—S. syncline (complementary to the Pennine anticline) with a considerable pitch to the south, the ground N.W. of Todmorden shows a prevailing westerly dip in the beds. In the latter case, however, the succession of higher beds in a westerly direction is broken by a pair of faults which, diverging towards Burnley, let in a wedge-shaped trough of Middle Coal Measures between Holme and Burnley.

Steep westerly dips characterise the Lancashire side of the Pennine anticline, in contrast with the low easterly dips on the Yorkshire side; in other words, the fold is here monoclinal rather than anticlinal. The 'Anticlinal' fault to which great tectonic importance was ascribed by Hull,[1] has been shown to be of relatively minor effect in this region, for it has been possible in many places to trace an apparently unbroken succession across the western limb of the anticline. The main line of fractures lies more to the west.

While the mapping of the original survey has in a broad sense held good, certain modifications have been effected. The sandstones of the Lower and Middle Coal Measures have been mapped for the first time. Recent information from borings, collieries and outcrop workings has been utilised to modify the outcrop lines of various coal-seams; several additional seams, chiefly in the Lower Coal Measures, have been traced on the six-inch maps as far as possible. The Millstone Grits, also, have been examined in greater detail than was formerly attempted, and more character has been infused into the study of the series; this is rendered desirable by the fact that the correct interpretation of many areas involving Coal Measures depends on the intelligent reading of the Millstone Grit succession.

The upper portion of the Millstone Grit series is now well known, and a complete detailed succession of the Lower Coal Measures has been established.

The beds below the Kinderscout Grit form small inliers at Scout Spa on Walsden Edge and immediately west of Blackstone Edge; they appear to owe their presence to local periclinal uplifts.

The faulting of the area considerably complicates the structure. The most important system has a N.W.–S.E. trend and is broadly confined to two main belts. The more powerful one ranges from Readycon Dean in the south, passes west of

[1] E. Hull, 'The Geology of the Burnley Coalfield' (*Mem. Geol. Surv.*) 1875, pp. 9 and 100–101.

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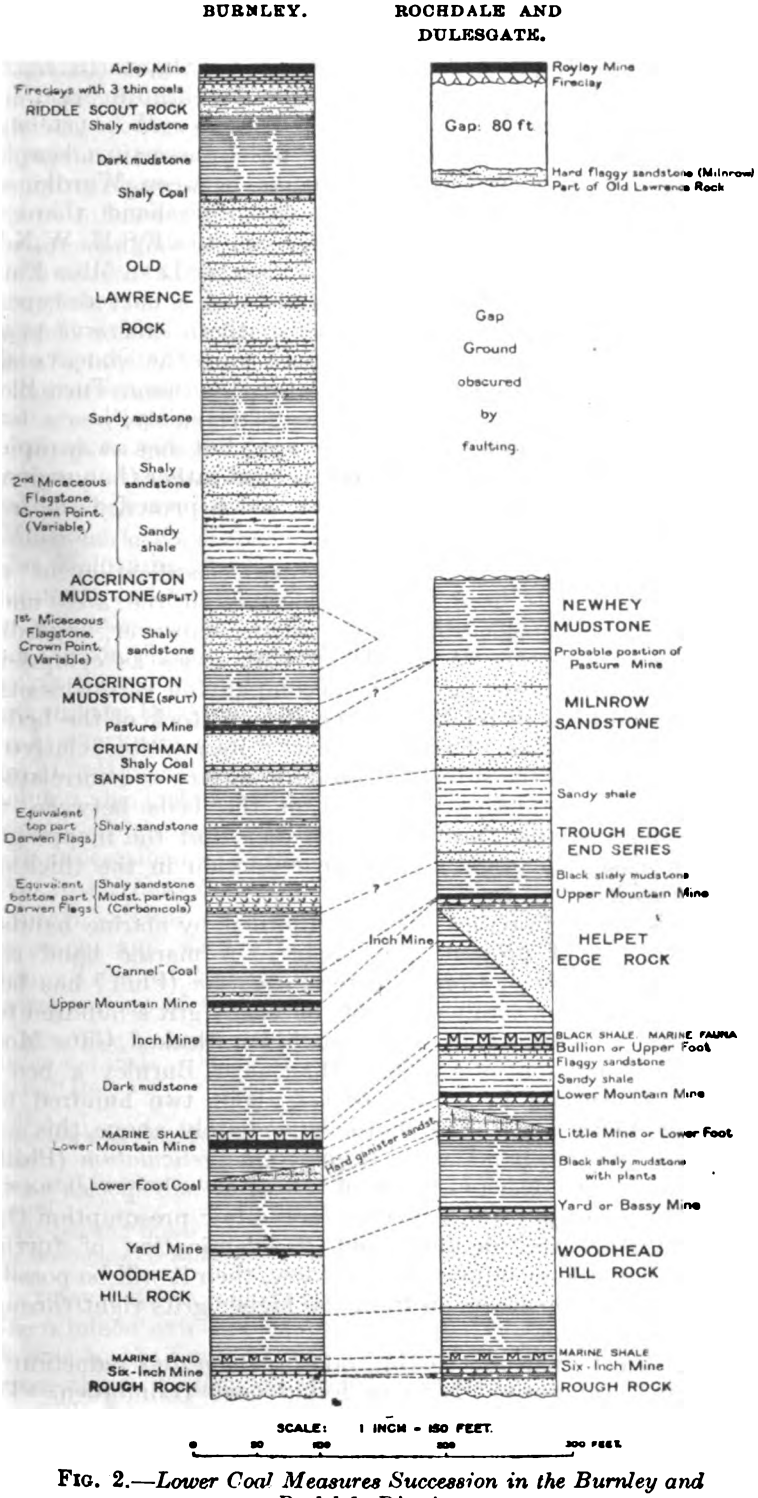

FIG. 2.—*Lower Coal Measures Succession in the Burnley and Rochdale Districts.*

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Todmorden, and reaches Burnley as the great Cliviger Valley Fault, with its zones of fracture on either side; the second belt of N.W. faults extends from Hollingworth Lake to Shawforth in the Whitworth valley and appears to continue in that direction. In the Rochdale area an important E.N.E.–W.S.W. system of faulting has been observed, the effect of which is seen in a complete repetition of the Lower Coal Measures between Wardle and Milnrow. South-east of Burnley, on the other hand, there are indications of this system having swung round to a E.S.E.–W.N.W. direction, an example of which is the Thieveley Lead Mine Fault.

In a few localities there are instances of a curved type of fault, trending east and west at the southern end and practically north and south at the northern end, the concave side facing east. A good example of this kind, between Turn Slack dam on Shore Moor, and the Longden End valley, has a large downthrow in the middle part of its course, but dies away rapidly in both directions. This type of fault is local rather than regional, and is probably related to the folding which preceded the fault systems previously mentioned.

Millstone Grits.—The original broad classification of the Millstone Grits has been found applicable in the area under consideration. Considerable doubt exists, however, regarding the former conception of the Third Grit series as comprising several beds of massive grit. The accompanying vertical section shows the position in relation to the Rough Rock of the bed at present referred to as 'The Third Grit'; its position relative to the Kinderscout is the subject of present enquiry and correlation. Nowhere has an unbroken section of the beds between the Kinderscout and the Third Grit been seen, but the mapping of the past season suggests a probable reduction in the thickness formerly assigned to these beds.[1]

In this connection the evidence afforded by marine bands is suggestive but at present inconclusive. A marine band containing a mutation of *Glyphioceras reticulatum* (Phill.) has been found lying above a coal which rests on flaggy grit a hundred feet above the Kinderscout in Dry Clough on Bleaked Gate Moor. In Rams Clough on Worsthorne Moor near Burnley a bed of flaggy grit overlain by a coal occurs about two hundred feet below the Third Grit. The shales immediately above this coal contain a marine band with *Glyphioceras reticulatum* (Phill.), which Mr. Bisat considers to be of the same sub-species as the one in Dry Clough. There is, therefore, a fair presumption that the two bands are identical, and, if examination of further material should lend support to this view, then it will be possible to reconstruct the succession from the higher grits right through to the Kinderscout.

More direct evidence bearing on the suggested reduction of the 'Third Grit Series' is to be found near Todmorden. The

[1] 'The Geology of the Burnley Coalfield' (*Mem. Geol. Surv.*), 1875 p. 40.

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massive, coarse (and sometimes conglomeratic) grit which makes bold crags on the S.W. side of the Cliviger gorge at Lydgate, was formerly mapped as a member of the Third Grit Series. The bed is now definitely considered to be Kinderscout Grit; it can be traced to the country south of Todmorden, where its stratigraphical relationships again place it as Kinderscout. Confirmatory evidence for this conclusion is supplied by the discovery of a marine band lying between two and three hundred feet below this grit and bearing a strong resemblance in its fauna to a band in Crimsworth Dene which occurs below proved Kinderscout.

At least six definite fossiliferous horizons have been established between the Kinderscout Grit and the Rough Rock; and while the recognition of these bands has proved of considerable help in the correlation of certain isolated exposures, the confirmation they afford to the lithological mapping alone emphasises their importance. The positions of these marine horizons in relation to the lithology are seen in the accompanying vertical sections of the Millstone Grits (Fig. 3).

The Holcombe Series[1] in this district shows remarkable development and variation. Fine natural sections of these beds, along with other members of the Millstone Grit Series, are to be seen in Greens Clough, Portsmouth; in Paul Clough and Swinden Water on the moors north of the Cliviger valley, and in Gorpley Clough and the Dulesgate valley near Todmorden. The Holcombe Series is everywhere in this area defined by a coal (the 'Holcombe' Coal) which lies at the base of the mudstones and shales underlying the lowest bed of Haslingden Flags; constant with this coal is also a marine band 20–30 feet above it, characterised by an undescribed species of *Gastrioceras* and a mutation of *Glyphioceras reticulatum* (Phill.), which are being dealt with by Mr. Bisat. Below this coal, however, considerable variation takes place, and widely different facies are observed at this horizon. Thus, at Ratten Clough Wood, near Portsmouth, the following section of the Holcombe Series is seen :—

Haslingden Flags. Lower Bed.	—
Mudstone and shale with marine band 30 feet from base	60 feet.
Coal (the 'Holcombe' Coal)	6 inches.
Fireclay	3–4 feet.
Variable dark sandstone and sandy mudstone	6–8 feet.
Coal smut	—
Fireclay and fireclay mudstone (average 12 feet good fireclay)	15 feet.
Coal smut	—
Fireclay, passing down into sandy fireclay mudstone	6 feet.
Strong fine siliceous sandstone; variable character	15 feet.

The fireclay between the two coal smuts is of good quality and has been mined extensively from adits driven into the hillside.

A mile to the north-east in Paul Clough, the Holcombe Coal rests on about 25 feet of sandstone and sandy shale with no trace of the lower coal smuts, which character is maintained in

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 40.

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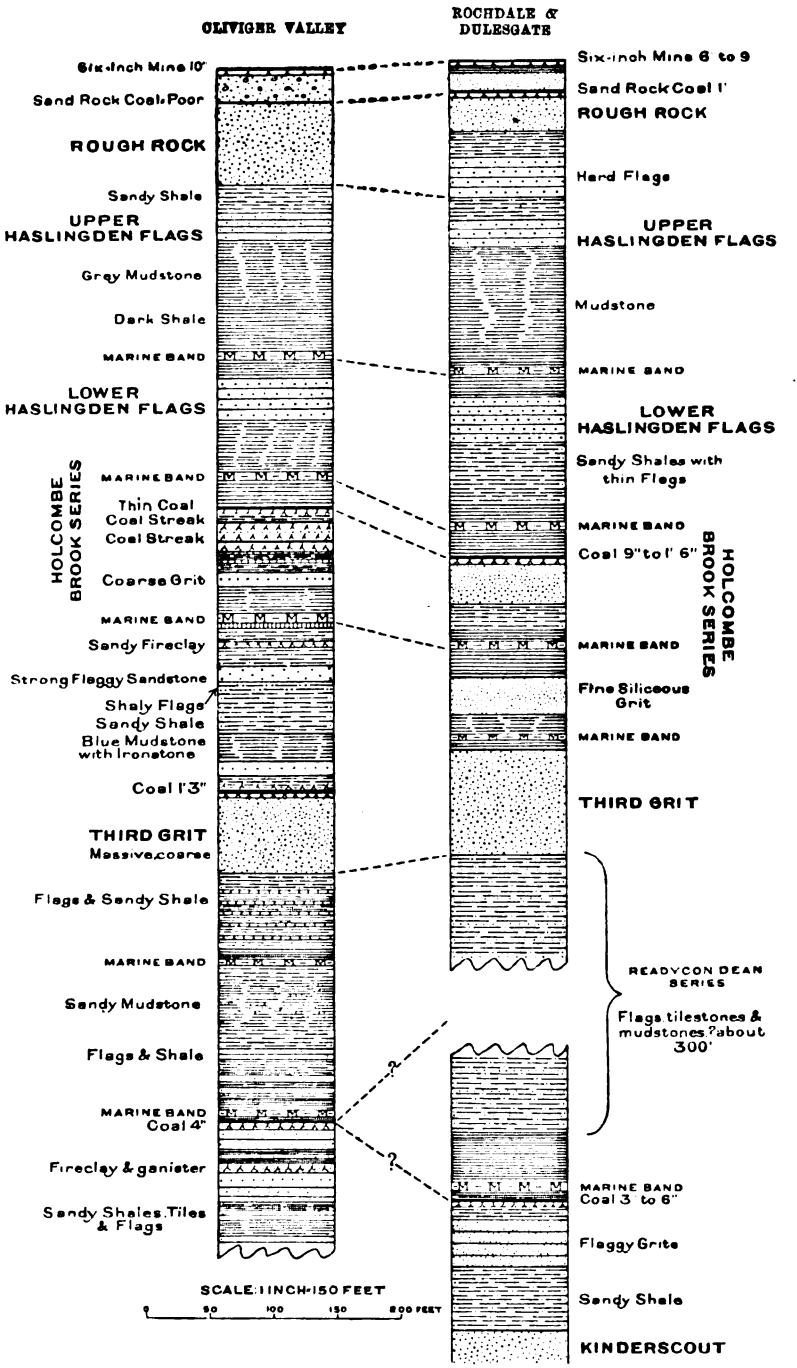

FIG. 3.—*Millstone Grit Succession in the Burnley and Rochdale Districts.*

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a northerly direction across the Worsthorne Moor to Swinden Water. The same replacement of the fireclay series by sandy material is observed as the beds are traced south from Ratten Clough Wood to Dulesgate, where a fairly massive grit, ganister-like at the top, immediately underlies the Holcombe Coal. Coincidently with this general development of sandy beds in a southerly direction, the sandstone at the base of the series in Ratten Clough Wood appears to be largely replaced in Greens Clough, Portsmouth, by grey mudstone.

Little further can be said at present concerning the relation to the succession now detailed, of the Millstone Grits mapped last year on the east side of the Pennine anticline. It would appear, however, that the beds then described as 'The Third Grit beds'[1] correspond in part to the Readycon Dean Series of the Rochdale district, and nowhere reach the horizon of the Third Grit.

Lower Coal Measures.—Between Burnley and Rochdale the Lower Coal Measures occur chiefly on the west (upthrow) side of the Cliviger Valley Fault. On the downthrow side of this great fault a complete succession of Lower Coal Measures crops out in the Cliviger valley between Redwater Clough and Riddle Scout; the tracing of individual beds, however, is here complicated by extensive land-slipping. From this point a belt of Lower Coal Measures extends almost due north across moorland country, where the 'mountain mines' have been little exploited owing to their inaccessibility and the high dip of the beds at their outcrop.

Between Todmorden and Rochdale the lower beds of the Lower Coal Measures are subjected to frequent repetitions by powerful north and south fractures. And as all the workable coals are confined to the lower beds, exploitation by outcrop and shallow workings is thus both facilitated and extended.

The higher beds of the Lower Coal Measures are concealed under a thick covering of drift around Rochdale, but are widely exposed over the country north of the Dulesgate valley. Especially good exposures occur on the moors and in the cloughs N.W. and S.E. of Thieveley Pike.

Outcrop and adit workings commenced at Easden Wood, Deerplay, during the coal strike of 1921 have been extended by the Deerplay Collieries, Ltd. The throw of the Thieveley Lead Mine fault[2] is here demonstrated very clearly, the Arley Mine, Lower and Upper Mountain mines outcropping in close proximity. All three coals are worked, and small additional areas in the Arley and Upper Mountain have been proved. The tipped material from the Lower Mountain Mine workings in Black Clough affords an excellent opportunity for examining the marine shales, bullions and coal balls associated with this horizon.

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[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 43.

[2] 'The Geology of the Burnley Coalfield' (*Mem. Geol. Surv.*), 1875, p. 85. The throw of the fault probably does not exceed 900 feet.

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Only two marine horizons have been found. One, well known as the Bullion Bed, overlies the Bullion or Upper Foot Coal and has already been referred to.[1] It has been observed, though, that while the occurrence of bullions is sporadic, the black shales overlying the coal everywhere contain the marine fauna. It is to be noted also that bullions are by no means confined to this bed.

The other marine band occurs in the shales immediately overlying the Six-inch Mine, at the base of the series; the coal with its fireclay usually rests directly on the Rough Rock, but is occasionally separated from it by several feet of shale. This is the case on the south side of Dulesgate. The Six-inch Mine marine band contains *Pterinopecten*, *Posidoniella*, and goniatites, but the poor state of preservation renders specific determinations difficult.

A bed rich in *Lingula* (?), but containing no other shells, has been seen in several localities five feet above the Lower Foot or Little Mine; this, however, would appear to represent an estuarine rather than a marine incursion. Plant remains are common at many horizons, notably towards the base of the series.

A fairly uniform character throughout the area is observed in the lower beds up to the horizon of the Lower Foot Coal. The latter is usually separated from the Lower Mountain (or Ganister) Mine by 30 feet of black shale, but between Dulesgate and Greens Clough the shales are largely replaced by a hard white sandstone. Considerable change also takes place in the same area, between the Lower Mountain Mine and the Bullion Coal. North and west of Littleborough these coals are separated by 36 feet of sandstone and sandy shale, while at Clough Foot, in the Dulesgate valley, only 3 feet of shale intervene.

The two coals coalesce immediately north of Clough Foot, and throughout the district mapped to the north only one coal occurs at this horizon. The coals come together somewhat abruptly on Inchfield Moor; the intercalated sandstone is seen to die out rapidly in the Foulclough colliery workings and both seams crop out in close proximity on the northern slopes of Inchfield Moor. As a result of this union the marine band overlying the Bullion Coal becomes associated with the Lower Mountain Mine in the Burnley district.

Where the Lower Mountain Mine and the Bullion Coal are separated, the former is of good quality, but the Bullion Coal is often impregnated with pyrites. The following section[2] of the

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[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 42. *N.B.*—This marine horizon overlies the Lower Mountain Mine in the north of the area.

[2] We are indebted to Mr. T. Walton, manager of Rowley Colliery, Burnley, for this and other information.

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Lower Mountain Mine at Bank Hall Colliery, Burnley, where the two coals are united, is thus of interest :—

Coal with irregular cannel streaks and iron pyrites which partly infiltrate the middle portion - - - - - - - - -	15–16 inches
Good coal, comparable with Lower Mountain Mine where latter is separated - -	18 inches
Pyritous coal with streaks of dirt - -	12–14 inches

The Helpet Edge Rock[1] underlying the Upper Mountain Mine in the Rochdale and Milnrow districts dies out in a northerly direction; around Burnley the Lower and Upper Mountain mines are separated entirely by mudstones in which the Inch Mine and fireclay occur about 25 feet below the Upper Mountain Mine. This mudstone facies, along with the Inch Mine, persists over the moors on the west side of the Cliviger valley, and for some distance south of Dulesgate. Occasionally, however, the fireclay seat of the Upper Mountain Mine rests on several feet of flaggy sandstone, which may be regarded as a feeble representative of the Helpet Edge Rock. The latter is also represented in the narrow belt of Lower Coal Measures north of Cornholme by a bed of hard fine flagstone which extends down almost to the Inch Mine.

The ' Cannel ' Coal, lying from 3 to 8 yards above the Upper Mountain Mine in the Burnley district, appears to be quite absent south of Heald Moor. It is very probable that a union of the two seams takes place. At Easden Wood and Black Clough on Deerplay Moor the coals are separated by 10 to 15 feet of fireclay and sandy mudstone, which, together with the Upper Mountain Mine, thin to the south, while the Cannel Coal is seen to thicken in the same direction in the workings of the Easden Wood Colliery; and when next seen in Greens Clough, still farther south, the beds contain but one coal at this horizon.

Between Rochdale and Dulesgate a persistent bed of flags lies about 30 feet above the Upper Mountain Mine. It is typically developed at Trough Edge End, where it has a thickness of 30 feet. North of Dulesgate the flags thin out along the west side of the Cliviger valley, and are represented by only a few feet of flaggy sandstone. On the opposite side of the valley, however, a 15-ft. bed of hard fine flagstone is seen in Cartridge Clough at this horizon, and increasing in thickness to the north, gives rise to the feature of Pike Hill on Worsthorne Moor. This bed of sandstone is the equivalent of the Darwen Flags of the country to the west.

The Pasture Mine is seen only in the northern half of the area, and even there its occurrence is inconstant. The sandstone (the ' Crutchman ') underlying the coal in the Bank Hall Colliery shaft increases in thickness and strength to the south; as a massive fairly coarse sandstone it makes a strong feature

[1] ' Summary of Progress for 1921 ' (*Mem. Geol. Surv.*), 1922, p. 42.

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over Todmorden Moor, where it is at least 60 feet thick, and is overlain by a fireclay varying in thickness from 1 to 6 feet, which is worked near Sharneyford.

Farther south, near Rochdale, the 'Crutchman' is represented by the 90 feet of hard flaggy sandstone quarried at Milnrow, but the Pasture Mine and fireclay are here apparently absent.

A thick fireclay horizon with coal streaks occurs at the horizon of the Pasture Mine in Cartridge Clough, north of Cornholme, and borings indicate the presence of the coal and fireclay under Worsthorne, several miles farther north. It is clear, however, from a comparison of these borings with the sections of the new reservoir at Hurstwood[1] that in less than a mile the Pasture Mine passes into black shale and the fireclay disappears. As the reservoir lies between Worsthorne and Cartridge Clough, the significance of the appellation 'The Gay Deceiver' already applied to this seam[2] is here well demonstrated.

The Accrington Mudstones form a characteristic horizon everywhere, overlying the 'Crutchman' sandstone, but their thickness varies considerably. When traced east from Accrington into the Burnley district, they are seen to take in flaggy beds, which reduce the workable thickness of the series for brickmaking purposes. Farther south the mudstones (known as the New Hey Mudstones) are worked extensively for brickmaking around Rochdale, where a thickness of 60 feet has been proved; the top, however, is not seen, and over much of the ground they are buried under drift.

The Old Lawrence Rock, which succeeds the Accrington Mudstones, is sometimes mappable as two beds; this is the case at Easden Wood, on the northern part of Deerplay Moor, and in the Cliviger valley south-east of Riddle Scout. In the last named locality the intercalated mudstones resemble the Accrington Mudstones, but as a rule the weak partings, where they occur in the Old Lawrence Rock, consist of sandy shale.

In the north, the Old Lawrence Rock is typically developed east of Worsthorne, where owing to its low dip, it makes a great surface spread, and has been quarried in the past for building stone; its outcrop is terminated on the west by a fault which ranges N.W. through Worsthorne village and throws down Middle Coal Measures on the west.

A constant feature in the upper part of the Lower Coal Measures is the 50 feet of shale and mudstone which intervenes between the top of the Old Lawrence Rock and the base of the Middle Coal Measures. The Riddle Scout Rock, a bed of sandstone similar to the Old Lawrence in character, everywhere separates these mudstones from the seat earths and thin coals

[1] Acknowledgment is made to Messrs. Mackenzie & Baldwin for readily given help and information.

[2] A. J. Tonge, 'Sinking into the Lower Coal Measures at Hulton Colliery,' *Trans. Man. Geol. Soc.*, 1910, vol. xxxi, p. 256.

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below the Arley Mine. It has nowhere been seen to exceed a thickness of 20 feet, and often contains shaly partings.

These higher beds of the Lower Coal Measures, as has been mentioned previously, are mostly obscured by drift where they occur in the Rochdale district. The exposure of massive sandstone at Belfield Mill in the Beal valley, appears to be the local representative of the Old Lawrence Rock.

Middle Coal Measures.—The Middle Coal Measures occupy the relatively low, drift covered ground, and good natural sections are therefore rare. The succession of the lower beds is well seen, however, on the north-east side of the Cliviger valley between Riddle Scout and the Lowe; the Arley, Dandy, and China coals being each associated with a prominent escarpment. Numerous records of borings and pit sinkings have provided valuable material for supplementing field observations in the drawing up of a complete succession from the Arley (or Royley) Mine at the base, to the Dog-Hole Coal, representing 1,030 feet of strata. The chief coals are shown in the accompanying vertical section.

In the Rochdale district the Middle Coal Measures are contained in an area of less than one-sixth of a square mile. A little over 300 feet of measures have been proved above the Royley Mine, and comparison with the Burnley succession reveals considerable lateral variation. The Bottom Neddy or Smith Coal appears to be the equivalent of the Dandy Mine of Burnley, in which case the Bone Coal would represent the Crackers Mine.

Glacial Drift.—Loamy gravel, with interbedded red sand (the latter dug for industrial purposes) is the predominant type of drift in Rochdale district; most of it appears to be of morainic origin. Boulder-clay, chiefly of the Ribblesdale type[1] is prominent around Burnley, particularly on the east side, where it ascends to over a thousand feet above sea level.

The progressive stages of retreat of the ice are indicated by numerous overflow channels; the series north of Littleborough appear to have discharged their waters into the Summit gorge, which probably marks the final overflow. At this stage the Calder valley received the waters from the Summit gorge and also the overflow from the Burnley district *via* the Cliviger gorge. The several overflow channels notching the ridge on the north side of the Cliviger gorge mark the escape of the water impounded in the Sheddon and Thursden valleys, at the time when the natural outlets of the latter were blocked by the ice sheet.

The area surveyed by Mr. Tonks embraces the town of Burnley and the district of Habergham Eaves. The Lower Coal Measures are well exposed in many natural sections notably in New Barn Clough and in Habergham Clough and its tributaries. The succession is everywhere the normal one

[1] A. Jowett, 'Glacial Geology East of Lancashire,' *Quart. Journ. Geol. Soc.*, vol. lxx, 1914.

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given on p. 47, except in one or two cases. In New Barn Clough, for instance, the Upper Mountain Mine is underlain by about 8 feet of flaggy sandstone and sandy shale. These beds are the local equivalents of the Helpet Edge Rock of the Rochdale district. Again, the Pasture Mine is exposed near Wholaw Nook and in Copy Clough in its normal development, but towards the south-east it dies out. A shaft was sunk from the Arley Mine to the Lower Foot at Bank Hall Colliery just before the war. Specimens of this valuable section have been preserved, and have been examined by permission of the proprietors of the colliery[1]. The accompanying vertical section (Fig. 2, Burnley District) is based on this record. At Bank Hall the Upper Mountain Mine is being got below the old workings in the Arley.

Middle Coal Measures.—The Middle Coal Measures lie in the trough of the Burnley syncline. South and south-west of Burnley the southerly limb of this syncline gives rise to a country dip of 10°–12° to the north-north-west. Northwards the dip changes in direction. West of Burnley it is 8° to E.N.E.; and east of the town it is 6° to W.S.W. The structure, therefore, is that of an elliptical basin with its long axis trending approximately W.S.W.–E.N.E.

The basin is broken by many faults. The big faults are remarkably constant in direction, and run N.N.W.–S.S.E. Smaller faults, running approximately east and west, cross between the main lines of faulting. The north-westerly faults are not simple fractures, but are, as a general rule, narrow and complicated fault belts. One big fault is frequently accompanied by a series of smaller compensating faults, which throw in the reverse direction to the major fault of the belt. Other fault belts attain their total throw by a series of small steps, all throwing in the same direction. The net throw of each main fault belt, west of Burnley, is down to the north-east. The amount of throw is variable and inconstant. Big faults with a throw of several hundred feet frequently fork and die out in a few hundred yards.

The Middle Coal Measures are not well exposed in this district, as they lie in the low ground where the drift is thick. Many shaft sections are, however, available to supplement the information obtained from natural sections, and the general succession of the principal coal-seams is shown on the accompanying vertical section (Fig. 4).

A remarkable instance of lateral variation, accompanied by the displacement of at least two coal-seams, has been observed in this district. Fifteen yards below the Low Bottom Coal, the Inferior Cannel Coal rests on a thick sandstone. This sandstone is exposed in the Whitegate and Lumb Wood Quarries, Habergham; and in Sweet Clough, just north of Lowerhouse Mill. It is a

[1] The executors of John Hargreaves, Ltd. We are greatly indebted to the Managing Director of this firm, Mr. Richard Landless, for many valuable sections, plans and records of mines in the Burnley district.

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fine-grained grey and brown sandstone with some mica, false-bedded, and concretionary and ferruginous in parts. Towards the base it becomes coarser. It occurs in massive lenticular beds

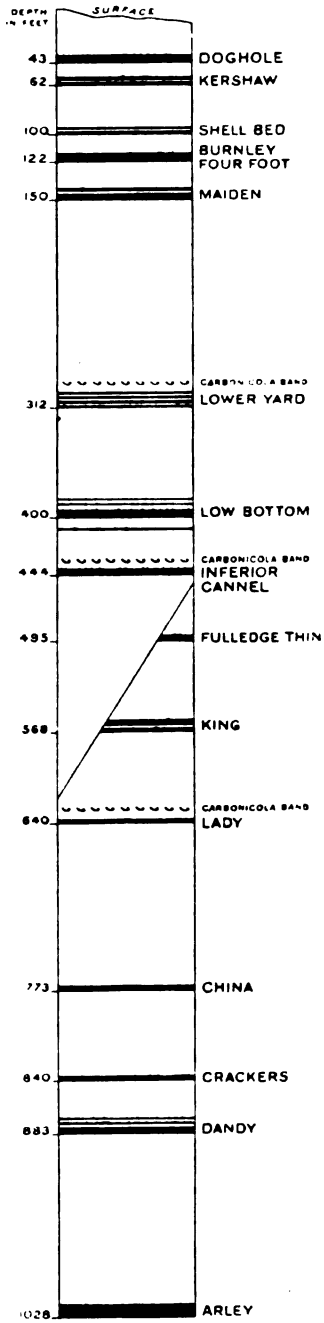

FIG. 4.—*Section showing the sequence of the chief coal seams of the Middle Coal Measures, Burnley District.* (*Depths in feet.*)

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with irregular partings of sandy shale, which is crushed and thrust between the massive lenticles. This sandstone was 121 feet thick in the Habergham Pit Shaft, and 132 feet in the Clifton Colliery Shaft. The King Mine and the Fulledge Thin Mine (*see* Vertical Section, Fig. 4) were absent in both these sections. In the Bank Hall Colliery Shaft the sandstone was 103 feet thick, and rested on the King Mine. When the King Mine was being worked at Bank Hall it was found that the sandstone roof descended and cut out the coal about 500 yards north of the colliery. The sandstone was formerly exposed in the old Pickup quarry, south of the Infantry Barracks. Here it rested on the King Mine. The increase in thickness takes place in a northerly direction; and the base cuts transgressively across the underlying measures. It is considered that the transgression is part of a great 'wash-out'[1] in the Middle Coal Measures.

The thick coal-seams above the Low Bottom Coal were formerly exposed and worked in the centre of the synclinal basin under Burnley. They are now exhausted, and no new evidence has been obtained as to their position or character.

Glacial.—A thick drift mantle covers the low-lying ground on which Burnley stands. This cover thins southward on the lower slopes of Hapton Park, and on the top of Hameldon Hill only scattered erratics occur. About 3 feet of laminated clay is seen west of Lumb Wood quarry and appears to be thinning westwards. It rests on stiff grey till with limestone boulders ('Ribblesdale Drift' of Jowett). A similar wedge of laminated clay occurs on the side of Hapton Clough near Old Barn Farm. Beds of laminated clay are reported as being frequently exposed in digging for drains, etc., under the town of Burnley. Glacial striæ, running due S.E., have been found on sandstone at Habergham Quarry.

4. Cumberland District

Headquarters : Whitehaven

Bernard Smith, M.A., District Geologist.
E. E. L. Dixon, A.R.C.Sc., B.Sc. } Senior
T. Eastwood, A.R.C.Sc. } Geologists.
F. M. Trotter, B.Sc.
S. E. Hollingworth, B.A., B.Sc. } Geologists.
L. H. Tonks, M.Sc.

Mapping in the Carlisle area was actively advanced by Messrs. Dixon, Trotter, Hollingworth and Tonks. Some time was spent by the senior geologists in training the younger members of the staff.

[1] Compare, for example, the Parkgate 'wash-out' in Yorkshire, described by Prof. P. F. Kendall—Presidential Address, Section C, British Association Meeting, Hull, 1922.

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In the Whitehaven district the year's work was chiefly undertaken by Messrs. Smith and Eastwood. Recent borings south of Egremont were examined by Mr. Smith.

Carlisle, Longtown and Silloth District

The mapping of the New Series Sheet 17 (Carlisle) has been completed and the smaller Sheets 16 (Silloth) and 11 (Longtown) have been resurveyed. Sheet 18 (Brampton) has been commenced.

CARBONIFEROUS

Mr. Trotter has mapped a limited spread of the Scottish Carboniferous Limestone Series lying in Sheet 12 (Shopford), east of Sheet 11. The rocks are purple and grey sandstones and purple and chocolate shales with minor beds of limestone, cementstone and conglomerate. The sandstones are fairly easily distinguishable from the St. Bees Sandstone but more difficulty is experienced in distinguishing between the chocolate Carboniferous shales and the St. Bees Shales. Similar beds are recorded from a borehole at Riddings (p. 61).

NEW RED SERIES

In the Carlisle district some exposures have been found by Mr. Dixon in the upper part of the Trias that throw light upon the much-debated question of the local sequence of these rocks.

Three different interpretations of the sequence in the district have been advanced :—

T. V. Holmes.	*Prof. Gregory.*	*Present Grouping.*
Lower Lias.	Lower Lias.	Lower Lias.
Stanwix Shales.	Stanwix Shales.	Stanwix Shales. (of Abbey Town boring).
Kirklinton Sandstone.	Kirklinton Sandstone.	Kirklinton Sandstone.
Upper Gypseous Shales. (of Abbey Town boring).		
St. Bees Sandstone.	St. Bees Sandstone.	St. Bees Sandstone.
Lower Gypseous Shales.	Gypseous Shales. (of Abbey Town boring).	Lower Gypseous Shales.
Penrith Sandstone.	Penrith Sandstone.	Penrith Sandstone.

Holmes' sequence, the evidence for which has been stated clearly and in detail in several publications,[1] may be said to be that most generally accepted. As, however, the distribution of the beds referred by him to the Upper Gypseous Shales postulates an unconformity between the Lower Lias and the Trias of a magnitude unknown elsewhere in the country, his views have not been adopted on the map published by the Geological Survey, which omits the 'Upper Gypseous Shales,' and shows the St. Bees Sandstone as followed by the Kirklinton Sandstone directly, and the Stanwix Shales as underlying the Drift of Abbey Town.

[1] 'The Permian, Triassic and Liassic Rocks of the Carlisle Basin,' *Quart. Journ. Geol. Soc.*, vol. xxxvii, 1881, pp. 286–98; 'The Geology of the Country around Carlisle' (*Mem. Geol. Surv.*), 1899; and 'On the Evidence as to the Geological Structure of Cumberland bordering the Solway,' *Geol. Mag.*, 1915, pp. 410–18.

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This accords with what has been learnt during the recent revision.

In the country north of Carlisle Mr. Trotter finds no evidence that calls for an unconformity between the St. Bees and Kirklinton Sandstones.[1] Again the 'Kirklinton' upper part is overlain by the Stanwix Shales, but to the south-west the latter formation had not been identified, and Holmes has concluded that in this direction it is overstepped by the Lias; for at the Abbey Town boring, he found that the formation beneath the Drift, though consisting of red and variegated shales like those of Stanwix, carried much gypsum, and that the underlying sandstone, at a depth of only 43 feet beneath the shales, resembled St. Bees Sandstone.

It has now been found by Mr. Dixon that along the River Caldew, south-west of Carlisle, the Stanwix Shales are present in normal sequence between the Kirklinton Sandstone and the Lias, and extend right across the area shown as Kirklinton Sandstone on the map that illustrates Holmes' view.[2] The Stanwix Shales rest upon both brightly-coloured and pale grey beds of Kirklinton type, and apparently dip northwards beneath the Liassic plateau, under which red shales with gypsum were found near Great Orton in a boring made in 1781. These newly discovered field-relations dispose to a great extent of the difficulty of correlating the gypsiferous shales of Abbey Town with the Stanwix Shales of Carlisle.

The difficulties introduced by Prof. Gregory's correlation, although he points out various obstacles in the way of accepting Holmes' theory, are even greater than those it was designed to overcome. Arguments in favour of the view now accepted and against the views of other writers will be discussed in the forthcoming memoir.

In the ground examined by Mr. Hollingworth, in the neighbourhood of Thursby and Aikton, Glacial Drift conceals the outcrop of the Triassic rocks, but an interrupted section of the Gypsiferous Shales and Marls and the overlying St. Bees Sandstone was found extending for three-quarters of a mile along the Boston Beck and its upward continuation, Jacobs Gill, dipping at about 10° downstream. The dip of the St. Bees Sandstone, in which marly beds are rare, averages 15° to the N.N.W. The drift-covered depression between this exposure and the Liassic plateau allows for a considerable breadth of outcrop of the higher divisions of the Trias.

On the northern flank of the Carlisle Basin, Mr. Trotter finds representatives of the Kirklinton and St. Bees Sandstones and underlying gypsiferous marls forming a syncline with an axial trend from S.S.W. to N.N.E. The base of the series is exposed in Carwinley Burn (Sheet 12), 600 yards east of the Longtown-

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 45.

[2] *Quart. Journ. Geol. Soc.*, vol. xxxvii, 1881, pl. xi; *Geol. Mag.*, 1915, pl. xiv.

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Penton road as 6 feet of coarse breccia dipping to the W.S.W. at 10°, overlying purple Carboniferous shales and coarse flaggy sandstone dipping N.N.E. at 50°.

A borehole at Riddings appears to have passed through 8 ft. 6 in. of surface clay into 97 ft. 9 in. of the marl series, with numerous hitherto unsuspected beds of gypsum and three layers of conglomerate (breccia). The lowest breccia, 1 ft. 3 in. in thickness, may represent the local base of the Trias. The lower part of the bore proved 363 ft. 9 in. of sandstones and marls of Carboniferous age.

It is estimated that the marls are at least 200 feet in thickness; they pass gradually into the St. Bees Sandstone, being replaced upwards by beds of chocolate shale in ever diminishing thicknesses, between thickening beds of sandstone.

A continuous section of St. Bees Sandstone, conformably succeeded by Kirklinton Sandstone, occurs in Carwinley Burn to the S.W. of the outcrop of gypsiferous marl.

In the west bank of the Esk, at Kirkandrews, and in the east bank for a distance of 600 yards S.W. of the Carwinley Burn, there are good sections of bright-red Kirklinton Sandstone—in the latter case very near the base of the group. The exposure of Kirklinton Sandstone at the lower end of Carwinley Burn covers a considerable extent of ground owing to the synclinal structure. Its thickness here is not more than 100 feet.

LIAS

No evidence has been obtained regarding the presence of Rhaetic beds beneath the Liassic plateau west of Carlisle. The Lias is exposed in two small stream sections, the one at Flat, south of Thurstonfield, the other near Thornby (S.E. of Aikton). Fossils have been collected at both localities. The other records are from wells in the Orton and Wiggonby districts; the well at Great Orton passed through Lias and ?Rhaetic into red shales with gypsum at 228 feet depth.

GLACIAL

The Carlisle area was invaded by a sheet of ice that radiated from the mountainous district around Criffel in the south of Scotland. The deposits have been found to be due to two advances of the ice and two withdrawals, resulting in a lower and upper boulder-clay separated by middle sands and gravels, and a series of later sands and gravels formed during the final withdrawal. During the latter period glacier-lakes were held up on the low ground between the ice-front and the higher ground to the north, east and south.

Messrs. Dixon and Hollingworth have discovered evidence of glacier-lakes to the south-west of Carlisle, associated with eskers, deltas and overflows that lie chiefly in the areas mapped by Messrs. Maden and Hollingworth.

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Mr. Hollingworth reports that the Lias plateau is thinly covered by drift with poorly developed drumlins, whilst to the south the lower ground is more thickly covered and drumlin topography is well developed. The Lower Clay is a stiff plastic clay which becomes sandy at some points where a considerable amount of Triassic sandstone has been incorporated. A continuous bed of Middle Sands 15–20 ft. in thickness was traced over an area of 3 square miles in the southern part of his district.

It is probable that the Upper Boulder Clay is spread over nearly the whole of the area mapped by Mr. Hollingworth. At some points it is exceptionally sandy.

Two groups of boulders were recognised : Lake District types, and local and Scottish or 'Irish Sea' types. The Lake District stones have, with rare exceptions, been found only south of the Lias plateau and have not been seen in the boulder-clays, whilst the Scottish types are common in both clays In the boulder-clay Triassic boulders are rare; they occur commonly in the upper glacial gravels by direct derivation from the solid. Mr. Hollingworth studied a group of three important lobed eskers in the low ground west of Thursby[1], running slightly north of west approximately parallel to the drumlins. The westerly trend is broken at intervals by sharp turns to the north, followed by a return to the original direction. These diversions appear to be across the drumlin ridges.

Deltas have been found at the mouths of a number of well-marked overflow channels at varying heights.

Mr. Tonks finds that the area inland of the Marine Alluvium is covered by boulder-clay in the form of long cigar-shaped ridges with steep-nosed fronts to the east and more gentle slopes to the west. Their alignment changes from N.E. near Old Mawbray to E. 23° N. at Highlaws and E. 10° N. at Waverbridge, indicating that the Scottish ice, travelling from a south-westerly direction, turned 35° eastward in a distance of 10 miles.

The only recognisable indicator-boulders are the Galloway granites. No Lake District boulders were found and no Middle Sands were observed. As in the ground surveyed by Mr. Dixon, the drumlins often have a steeper slope and shelf at various levels, *e.g.*, 50, 75 and 100 feet above O.D., apparently indicating the former existence of glacial lakes.

In addition to smaller patches a spread of Upper Sand and Gravel, covering nearly 4 square miles, south-west of Highlaws, was mapped by Mr. Tonks. Its elevation is from 145 to 150 feet above O.D., and it is concluded that it represents a deltaic mass formed in a lake, the overflow from which will be sought in the ground to the south.

Mr. Trotter finds the same quadruple arrangement of glacial deposits in the Longtown district. Middle Sands occur as high as 280 feet above sea-level. The Upper Sands are represented, in the neighbourhood of the Sark, by two spreads of sand and

[1] T. V. Holmes, 'Eskers and Kammes,' *Geol. Mag.*, 1883.

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gravel of deltaic origin; the southern at 100 feet, the northern at 140 feet above O.D.

Three persistent notches have been traced over the area at 200, 140 and 100 feet, and probably are the strand-lines of glacial lakes in which deltas were deposited at various localities.

POST-GLACIAL AND RECENT

Raised Beach.—The raised beach has been traced from a point a little south of Beckfoot to its termination at Grune Point, north of Silloth. The height of the beach, relative to high-water mark, decreases from Beckfoot to Grune Point; near Beckfoot it rests on the 3rd marine terrace; at Silloth on boulder clay, and at Grune on the 1st marine terrace. The beach has been formed by the addition of successive shingle ridges transverse to its length; its association with marine warps, indicates that, since the close of the Glacial period, the 'hook' has been travelling north-westwards, and that, as it has grown, the marine warps have accumulated in its front and lee.

Marine Alluvium.—The highest (3rd) terrace occupies a flat, three to four miles wide, which stretches from the coast to the boulder clay hills in the south and south-east, whilst the 1st and 2nd terraces are confined to Skinburness Marsh.

Submerged Forest.—Mr. Tonks reports the discovery of a Submerged Forest Bed at two hitherto undescribed localities.

A reef of dark and grey clay[1] emerges from a bank of sand, 1,250 yards S.S.W. of the bridge at Beckfoot and abuts seaward on the 'scar' known as Stinking Crag. The reef is 5 feet wide and lies 11 feet below high-water mark. During the summer of 1922 it was exposed for a distance of 120 yards, the section being as follows :—

Dark peaty soil, containing fragments of bark and leaves, with prone trunks and stools of trees ...	2 in.
Light grey clay (typical seat earth) with stones split by roots	6–12 in.
Stiff red boulder-clay with rootlets in upper part.	

Again on the southern edge of a boulder-clay 'scar' about half a mile north of Starry Hill, Skinburness, the following section was seen after high spring tides in September, 1922 :—

Dark peaty soil with five stools of trees	6 in.
Grey clay with splintered stones (base not seen) ...	6 in.

The submerged forest on Cardurnock Flats[2], was not visible during the present survey. Previous writers have ascribed this forest-bed to recent submergence; the magnitude however (over 11 feet) of the elevation necessary to raise it above the present

[1] Previously noted, but not described. *See* 'Report of the Royal Commission on Coast Erosion,' vol. i, 1907, pt. ii, p. 316a.

[2] T. V. Holmes, 'Notes on the Submerged Forest off Cardurnock on the Solway,' *Trans. Cumb. Assoc.*, pt. vi, p. 121.

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high-water mark, coupled with the fact that the raised beach has been continuously forming up to recent years, suggest that the period of destruction of the forest was anterior to the formation of the raised beach.

Workington, Whitehaven and Egremont District

The remapping of the Old Series Sheet 101 S.W. (New Series 28, Whitehaven) has been continued and much mining information has been obtained during the year.

SKIDDAW SLATES

A tract of Skiddaw Slates to the east of Cleator Moor was surveyed by Mr. Hollingworth who reports that on Flat Fell, Kinniside Cop and Dent, the rocks consist of alternations of thin buff and bluish-grey to black bands. The whole series appears to be sharply folded along axes pitching S.W. The least affected occur in the Merebeck as bluish-grey shaly and massive argillaceous beds. Mildly cleaved slates appear on the eastern portion of the ground mapped.

A number of dykes with a general N.W. trend have been discovered in the slates; some appear to be similar to those noted last year by Mr. Smith. In the neighbourhood of Nannycatch Gate a greater variety of dyke intrusions, ranging from light felspathic to dark basic types, is seen.

CARBONIFEROUS LIMESTONE SERIES

In the 'Summary of Progress for 1921,' the provisional grouping of the Carboniferous strata above the 1st Limestone, included the beds up to the Udale Coal as Millstone Grit, the rest being Coal Measures[1]. This was a purely lithological classification. Although the question is not definitely settled, sufficient palæontological evidence is now available to indicate that the bulk of these measures must be relegated to the upper part of the Carboniferous Limestone Series. The grit overlying the 1st Limestone—well developed at Overend quarry, Hensingham—will be referred to in future as the 'Hensingham Grit.' It has a thickness, as proved in two old borings in the neighbourhood, of 50 feet, while the beds above measure about 100 feet. Mr. Eastwood finds that the grit is succeeded by dark shales with thin and somewhat lenticular beds of limestone. These vary from dark earthy and sandy types to pale shaly and crinoidal, and yield a fauna determined by Mr. Pringle as being of D 3 horizon. Hence they are now placed in the Carboniferous Limestone. From the locality at Hensingham, where these limestone shale beds are admirably exposed, they are given the name of 'Snebro Gill Beds.'

The exposures of grit overlying the 1st Limestone in the area mapped by Mr. Smith about Bigrigg, farther south, with overlying

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 55.

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shales nearly up to the horizon of the black goniatite shales (which are definitely recognised as of Millstone Grit age) are now also relegated to the Carboniferous Limestone Series on palæontological evidence.

Mr. Eastwood reports that the Lower Carboniferous Rocks in the Distington area are brought to the surface by a dome fractured on the south-west by a large fault introducing the lower part of the Coal Measures and accompanied by minor faults roughly parallel to the major dislocation.

Carboniferous Limestone is well seen in the old Barfs quarries. Most of the rock exposed is 1st Limestone, but on the western side of the largest quarry, dark shales resting on what is probably the 2nd Limestone are introduced by faulting.

The coarse Hensingham Sandstone and Grit, overlying the 1st Limestone, appears on the west side of Barfs main quarry, behind the lime kilns, and again on the north-eastern side of an older quarry to the south-west. Farther north, the quarries of Barfs Silica Works, furnish excellent sections, though the relation of the grit to the underlying limestone has not been determined. The grit varies from medium to coarse and contains a fair amount of decomposed felspar and some white mica. The dip is to the north-east at 10°. Recent 'baring' operations have revealed an excellent glaciated surface with striae ranging N.N.E. and S.S.W. In a cutting from the quarries the grit is truncated to the south-west by a downthrow south-west introducing newer beds, consisting of dark shales, sandstone and ganister, together with the remnants of a coal seam and some calcareous mudstones and earthy limestones that yield a fauna similar to that of the Snebro Gill Beds. A ganister forming the upper part of the group apparently behaves normally outside the disturbed area and dips south-westward at a comparatively low angle.

In the Cleator Moor—Bigrigg—Gillfoot area the main limestones have been examined and mapped by Mr. Smith at numerous points, the average direction of dip being a little south of west. The 7th Limestone is exposed at the old Todholes quarries, near Cleator Moor, but no exposure of the 6th Limestone has been noted. A collection of fossils was made from the 5th in a railway-cutting between Longlands Mine and Clints quarries in which there is also a splendid exposure of the whole of the 4th Limestone. Here the divisions[1] recognised by C. Edmonds were examined in detail.

The 3rd Limestone forms a small scarp above the top of the quarry. Good examples of contemporaneous wash-outs in the White Limestones, filled with mottled shales, have been exposed recently. A fault trending north-north-westward, with a downthrow west of about 35 ft., traverses the quarry and breaks the western face about the centre of its extent. To the west of the quarry the Ingwell-Bigrigg Fault[2] repeats the higher

[1] *Geol. Mag.*, 1922, p. 74.

[2] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 54.

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part of the 4th Limestone; the Saccammina Limestone and shale and the overlying Junceum beds appear in old quarries east of the road from Bigrigg to Egremont.

Farther west the Orebank Sandstone and overlying beds up to the 1st Limestone are exposed near the old Lady and Wyndham pits of the Bigrigg Mines. To the south they are cut off by an east-and-west fault at the north end of Clintsbrow Wood. This fault throws northward and swings the outcrop of the Junceum beds westward to the west side of the Bigrigg—Egremont road.

In Langhorn Quarry some sandstone dykes, with a maximum thickness of about 4 inches, were discovered in long strike-joints in the 1st Limestone. These infillings descend at least as far as the Little Whirlstone and indicate that the 1st Limestone was consolidated sufficiently to be jointed before the deposition of the overlying Hensingham Grit. The infilling appears to differ slightly from the Grit.

The 1st Limestone occurs beneath the Breccia in the railway-cutting to the New Clints Pit.

South of the Langhorn quarry exposures of the different parts of the 4th Limestone occur in a highly faulted area. Most of the faults proved by mining have been detected at the surface where the beds are free from drift.

Southward, in the direction of Orgill and Egremont, the New Red Breccia rapidly cuts out the higher limestones, and rests upon different parts of the 4th Limestone.

MILLSTONE GRIT

Mr. Eastwood reports that the dark shales associated with a thin coal, believed to be the Udale Coal, exposed in Bedlam Gill, Hensingham, and overlying the beds of Snebro Gill, yield marine shells. Of these, goniatites are characteristic and indicate, according to Mr. Pringle, that the beds are of Millstone Grit age. Over the Whitehaven–Workington area, exposures are extremely rare, and strata below the Four Foot Coal down to and below the Udale horizon are seldom penetrated in shafts and borings. Nothing is known of the fossils apart from those of the beds just mentioned, while such evidence as exists in this area points to the absence of any marked development of grit or sandstone between those seams, the rest of the sediments being of Coal Measures type; so that even if the Udale Coal is taken as the base, the top of the Millstone Grit Series still remains in doubt.

COAL MEASURES

The mapping of the Coal Measures by Mr. Eastwood has been continued northwards to Workington. The area is thickly drift-covered and apart from occasional sections between Winscales and Workington, little is seen of the formation except in the coastal region south of Harrington. Below that place and Parton the beach, cliffs and coast ravines afford good sections. About midway between the two places the Micklam Fault reaches

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the coast. South of that fault measures from about the horizon of the Cleator Six Foot seam down to near the Main Band are seen. North of the fault strata from the Six Quarters Coal almost down to the Four Foot Coal are well exposed, though dislocated by faults. Of these rocks, nearly 200 feet in thickness, the upper half consists mainly of shales and mudstones—sandstones as a rule being thin or of bastard type. In addition to chance coals, two thin but persistent seams of coal occur here. The upper is overlain by several feet of grey-black shales containing scattered *Carbonicola* and brown-skinned ironstone cakes; it is separated from the lower coal mainly by light bluish-grey mudstones. The lower coal has a seat-earth of fair grade fireclay and is accompanied, some feet below, by black shales with a 'mussel band' associated with a bastard ironstone-fireclay rock in which cone-in-cone structure is well developed. The rocks are best seen in Andrews Gill and in the cliffs and beach from the south of Cat Gill to beyond Fox Pit Gill.

The lower half of these measures contains more arenaceous material and is separated by dark shales into two subdivisions both of which exhibit a development of ganister towards the top. On the beach the ganisters weather into rough surfaces upon which casts of *Stigmaria* are not uncommon. The sandstones of this group vary from fine to exceedingly coarse in the space of a few feet, both laterally and vertically, this being especially the case with the lowest one exposed on the beach west of Andrews Gill. Here the rock contains patches including fragments of quartz up to an inch in length, although adjoining portions contain lenticles of coal and pass into fine ganister. Little has been seen of the middle portion of the Productive Coal Measures, though they occur below the drift in the Workington area. In this neighbourhood mining has been long abandoned.

The Whitehaven Sandstone Series occupies the trough between two faults skirting the park of Gilgarron House, and is believed to come on again north of the Wythemoor Fault on Winscales. In this area arenaceous types only have been found and there is no reason to suspect the presence of higher beds containing Spirorbis limestone.

NEW RED SERIES

The basement breccia of the New Red Series is visible at several points in the Bigrigg-Gillfoot area. It overlies 1st Limestone in quarries near Orebank House, and in the railway-cutting to New Clints Mine, where it oversteps the limestone. It overlies the Hensingham Grit east of Orebank House and also in an old quarry immediately to the north. It caps the grit also in the neighbourhood of Croft Pit (Bigrigg Mines) and has been proved in many borings to the south and west, being shifted to and fro by the ore-bearing faults.

The most southern exposure occurs W.N.W. of Gillfoot House In this neighbourhood the breccia passes upwards into the St

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Bees Sandstone through red sandy marls with occasional breccias and veins of gypsum.

Specimens of breccia collected near Orebank House give evidence that the mineralization of limestone to hæmatite followed the deposition of the breccia. The chief facts are that the matrix of the breccia, enclosing larger isolated fragments of ore, has been itself converted to 'blue' ore; that the alteration occurs most commonly close to post-Breccia faults, and in breccia containing a high proportion of derived limestone fragments.

The St. Bees Sandstone is of normal type, with beds of chocolate shale at intervals. It is actively quarried at Bank End, west of the Bigrigg Mines.

In the Calder Bridge area, south of Egremont, the higher sandstones (probably equivalent to the Kirklinton Sandstone) contain a thick horizon in which æolian sand grains predominate.

GLACIAL

In the area examined by Mr. Eastwood the solid geology is almost completely masked by drift. Upon the east this is mainly boulder-clay, but on the west, from Harrington northwards, the clay is overlain by sand and gravel apparently of deltaic origin.

Mr. Hollingworth finds that the Ehen valley, apparently pre-glacial, was filled with alternations of cemented gravel, sand and red and chocolate clays, frequently laminated, through which the present stream now runs. The boulder-clay is of the red sandy Irish Sea type with Whitehaven and St. Bees Sandstone pebbles. The Nannycatch valley at the head of the Udale valley appears to have drained glacial Lake Ennerdale[1] at just below 700 feet and was joined at a later stage by a channel round the north-east of Flat Fell cut by waters from a lake at a little above 600 feet. A lower lake may have had an exit down the Nannycatch valley at Nannycatch Gate.

Mr. Smith finds that the stiff boulder-clay of the Cleator Moor and Bigrigg district becomes more sandy as it is followed south-westward over the sandstones. Here and there it contains patches of stiffer clay, probably dragged over the escarpment in the lower layers of the ice. A large part of the area, although free from true boulder-clay, has a sandy soil full of erratics.

A spread of Upper Boulder Clay, of which the first indications were found last year,[2] has been discovered south of St. Bees overlying the Middle Glacial Sands and Gravels. It is confined to a shelf between the cliff and the feature formed by the St. Bees Sandstone, and attains a maximum thickness of about 30 feet. It was considerably dissected during the second retreat of the ice—Deepgill Banks is a good example of a marginal drainage channel cut at this stage. Some sands and gravels, with a general E. to W. alignment, upon the higher ground to the east were probably

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, Appendix I, p. 124.

[2] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 68.

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formed in the early stages of the final retreat of the ice. Boulders of Carrock Fell gabbro and other well known Lake District rocks have been found on the beach and inland south of St. Bees. A series of fluvio-glacial sands and gravels has been mapped near Egremont.

5. Northumberland and Durham District
Headquarters : Newcastle-on-Tyne

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During the past season good progress was made with field-work on Lower Carboniferous rocks, so that the six-inch scale maps of the northern part of the county, from Berwick down to Wooler and Howick, have now been revised. In the Newcastle district work has been done round Capheaton and Corbridge, taking advantage of boring operations in progress at the time, and a revision of the Coal Measures around the city has begun.

The Lower Carboniferous rocks examined in the north of the county are in more extended sequence than those revised in 1921. In addition to the lower series (the Cementstones and Fell Sandstone, with the Scremerston Coals and Lower Limestones above), the Upper Limestone Group, ranging from the Great or Dryburn Limestone up to the Millstone Grit, is well seen on the coast at Howick. These rocks, when compared with regions farther south, show great attenuation, and as at least two unconformities are present, of unknown amount, a complete correlation with the Tyne area must be deferred until the intervening ground has been examined.

Cementstone Series.—Amongst the excellent sections along the Tweed and its tributaries, estuarine and fresh water remains are common enough, but apart from *Naiadites* and *Spirorbis* are in general too comminuted and fragmentary to be of value. Mr. Tait spent some time collecting plant and fish remains from the most promising localities. Particular attention was given to Lennel Braes, below Coldstream, a spot made classic by the researches of Witham, Milne Home and others; "petrified tree-trunks," with their internal structure well preserved, are fairly common here, along with fragments of *Eoscorpius*. Mr. Fowler also discovered crustacean remains at a new locality, half a mile north of Norham Castle, and amongst them Dr. Peach has identified *Crangopsis eskdalensis* (Peach).[1]

Scremerston Coals.—These seams thin southwards, and between Wooler and Alnwick their outcrop is difficult to trace,

[1] Known also from the Cementstones of the Blackadder section (Berwickshire) though more abundant in the Scorpion Bed of Langholm and Liddesdale immediately above the Fell Sandstone.

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owing to the heavy covering of drift and the paucity of old workings. Mr. Dinham reports that in the Till valley, N.W. of Chatton, they probably lie in a double fold, linked with the great Hetton anticline, though little or no direct evidence of their presence can be obtained. To the north-west, round Etal, the coals are in strong force, and in the past five or six seams have been wrought. Between Etal Colliery and Slainsfield the Fawcett, Blackhill, Main and Cooper Eye coals were mined from 50 to 80 years ago, the last named being the best in quality. At Ford Moss the Main Coal was the chief seam, the others having been wrought on a much smaller scale. This old colliery was again at work from 1910 to 1914, a cross cut having been driven to the Kiln or Diamond seam, between the Blackhill and Main coals : some of the waste material on the bing contains a distinctly marine fauna, including a small branching polyzoan, apparently a new species.

Lower Limestone Group.—The examination of the greater part of the coast section at Berwick-on-Tweed was completed during the 1921 field-season, but one or two doubtful points have now been satisfactorily settled by Mr. Fowler, who reports that the rock seen at low tide N. of the breakwater is the Acre Limestone with, as usual, an abundance of *Saccammina carteri*. At Burgess Cove there is a limestone horizon hitherto unnoticed, which probably agrees with that seen above the higher of the two Howgate Coals (so-called) 1¼ m. S. of Beal : it is a limy greenish marl, packed with *Lithostrotion* and other marine fossils. Mr. Fowler confirms the identification of the Marshall Meadows Limestone with the Dun, while another bed, seen in the cliffs E. of Brotherton's Hole, apparently represents the Woodend Limestone : it is curiously impersistent and seems to die out altogether towards the north.

In the Etal district, additional exposures of the Oxford Limestone have been noted near Brackenside, and on the eastern fringe of High Wood. Other alterations in the mapping have been occasioned by the recognition that the limestone quarried N. of Coldharbour is the Watchlaw, and not the Woodend Limestone. There are excellent sections of the last named seam in the Winterburn quarries, where an 18-inch coal, resting on a hard creamy marl, can be seen 30 feet above the limestone : this same coal, with its accompanying marl, outcrops E. of Woodend farm, and is no doubt the coarse coal used for lime-burning, seen in a similar position several miles to the E. near Fenwick.

The important section of strata between the Watchlaw and Woodend limestones, seen along the old whinstone quarries on Hazely Hill, has been measured. Amongst other information, this section affords the only demonstration as to the relative positions of the Doubster Oil-shale and the Watchlaw Limestone. On the coast S. of Spital the limestone is cut out by an unconformity of some size, and farther south the oil-shale apparently dies away altogether.

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In the North Charlton and Embleton district, Mr. Burnett reports one or two additions to our knowledge of the fine coast sections north and south of Embleton Bay. At Football Hole, there is an unusually clear example of the displacement of a N.E. fault by one trending N.W., while farther south at Cullernose Point, the cliff sections show that a local intrusion of the Whin Sill is later than the east-and-west faults, of which advantage has been taken by dyke-like 'feeders' of the overlying sheet of dolerite.[1] Mr. Gunn had reason to suspect this was the case from the behaviour of the sill in the Belford district, but there conclusive evidence is lacking.

A group of limestone outcrops 2½ miles W. by S. from Embleton village, which have not hitherto been identified, prove to be, in the main, repetitions of the Eelwell Limestone due to strike faults, followed to the S. by the Acre Limestone: these readings have been arrived at largely by palæontological evidence.

In the Alnwick district some preliminary work by Mr. Dinham has resulted in the identification of the Oxford Limestone, with its peculiar '*Girvanella*' nodules, in the river Aln, 1 mile E. of Alnwick. The persistence of this characteristic feature so far south should be invaluable in the interpretation of the doubtful ground S. of the town, where, apart from the Hobberlaw (Woodend) Limestone, no bed below the Eelwell has yet been identified.

Several limestones are seen in the stream section S. of Cawledge East Park, up to the Alnwick–Morpeth main road. The chief one, 12 feet thick, has *Posidonomya becheri* in the overlying shales, and if not the Budle Limestone, cannot be far from that position.

For several miles S. and S.E. of Alnwick the well-known Shilbottle Coal (a first class house coal lying between the Acre or Six-Yard and Eelwell limestones) attains its maximum development both in thickness and quality. The coal has been wrought continuously for a century or more, N. of Shilbottle, and in 1921 the Co-operative Wholesale Society began sinking two new shafts, which are to be 155 fms. deep. These should provide information of considerable geological interest, as they will pass through strata hitherto little known, for the ground is greatly obscured by drift.

The country from Newton-in-the-Moor southwards to the Coquet has been surveyed by Mr. Fowler, Mr. Maden continuing the work down to the Font valley. Throughout this area, continuous outcrops of the Great, Eight-Yard, and Six-Yard (or Acre) limestones are shown on the published maps. These have needed little alteration, for old quarries are numerous, and their evidence is supplemented by workings in the Shilbottle Coal beneath. The Great Limestone is still wrought for road-metal W. of Longframlington. It should be noted that in this region the Eight-Yard or Sandbanks Limestone is richer in *Saccammina*

[1] See also the excellent section by Professor E. J. Garwood in Bateson's 'History of Northumberland,' vol. ii (Howick Parish), Appendix iv, (1895).

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carteri than the Six-Yard (or Acre) Limestone, a condition reversed N. of Alnwick.

The Shilbottle Coal is in good state, down to the Coquet, being from 2 ft. 6 in. to 2 ft. 8 in. thick in the present working pits at Framlington and Healey Cote. Farther south, it begins to thin down, but is in workable condition as far as the River Font near Roughlees. At this point the old map shows the seam crossing the river immediately W. of the railway bridge, but some emendation is required here. It is true that a coal was got in the foundations of the reservoir dam at this spot, but it was 6 feet thick, and apparently of poor quality: some work had been done by 'pillar and stall,' from a shaft 19 feet deep. There can be little doubt that this is the thick, dirty coal, known farther north as the Beadnell Seam, and lying some way under the Eelwell Limestone. The Shilbottle Coal and Six-Yard Limestone probably lie farther down stream, under a cover of drift and alluvium.

During 1921–22 several borings were put down in the vicinity of Forestburn, in search of the Shilbottle Coal. One of these alongside the stream, 500 yards below the inn, passed through 72 feet of boulder-clay, and was then stopped, as it was evidently on the site of a pre-Glacial valley of some size. Another bore proved the Eelwell Limestone (hitherto not recorded in this district) 26 feet thick, with another one 40 feet lower. The cores showed that the last named bed was rich in *Spirifer*, a characteristic of the first limestone below the Eelwell in the Beadnell district.

In the Forest Burn at Wardshill there are excellent sections from the Eight-Yard Limestone down to the top of the Eelwell Limestone. The Six-Yard (or Acre) Limestone, with its characteristic shale above, full of large nodules of clayband ironstone, is well exposed, while the 'Little Limestone,' which is the chief 'mark' for the Shilbottle Coal, can be seen in a shaft alongside the stream. It is a pale hard stone, 2½ feet thick, lying 20 feet above the coal, a position in agreement with northern areas.

A large quarry for 'setts' and road-metal has been opened out in a branch of the Whin Sill, E. of Whitehouses. The working face shows 60 feet of dolerite, capped by a thin cover of soil and boulder clay, never exceeding 10 feet in depth. At the time of the original survey there seems to have been no surface evidence that such an extensive sheet of igneous rock was present. When first discovered 25 years ago the chief clue is said to have been afforded by debris noticed around rabbit holes in the open field.

Upper Limestone Group.—The coast and stream sections S. of Howick, supplemented by recent borings and shaft sinkings to the Shilbottle Coal at Wood House, afford a more or less complete account of the Upper Limestone Group, ranging from the Great Limestone up to the Millstone Grit. These measures attain their maximum development much farther south, towards the Tyne: although it has long been known that they were greatly attenuated in the Howick-Shilbottle district, no reading or detailed account

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of the sequence has been published hitherto. For over 20 miles N.W. of Howick practically nothing is seen of these strata until the Lickar-Lowick area is reached. Here they have been proved in two small synclines, at Lickar and Berrington, where the Lickar Limestone Coal, with the Parrot, Rough and Main coals below, were wrought out many years ago, above the Great Limestone (see Fig. 5). There are good exposures of the Parrot Coal (a micaceous, flaggy seam) in the stream W. of Berrington; and in the Lickar syncline, during the recent revision, a most interesting exposure of the Lickar Limestone was noticed near the mouth of the Lowick Burn. It is a dark, impure limestone, highly fossiliferous. Productí, lamellibranchs, (including a large *Pinna*), *Fenestella* mats, small gasteropods and trilobite tails are noticeably common: the richness and variety of the fauna distinguish the limestone from any other in North Northumberland. This information is of much value in reading the Howick sections. Thin limestones can be seen there, in the shales immediately overlying the Great Limestone, just as at Lowick: 20 fms. higher up a second limestone position (in two 1-ft. beds parted by shales) for which the name 'Cushat Limestone' is suggested, can be seen above the Howick Burn, but they are of normal crinoidal type. Much higher, in fact 80 fms. or more above the Great Limestone, a third bed is seen at several points on the coast section, and its characters at once recall the Lickar Limestone of the Lowick district. There are exposures in the cliffs E. of Howick and for a mile or more along the foreshore S. of Rumbling Kern. Confirmation of the reading is provided by Mr. Burnett's discovery of a parrot coal, exactly like the Lickar Parrot at Berrington, at the foot of the cliff S. of the great Howick Fault, 45 feet below the limestone. The other Lickar coals have almost disappeared, being represented by seams only a few inches thick.

From the mouth of the Howick Burn on to Longhaughton Steel, there is an ascending sequence well up into the Millstone Grit. The first two limestones seen above the Lickar are, as noticed by Professor Garwood, rich in *Productus latissimus*: still higher, in fact immediately beneath the coarse pebbly sandstone of the Millstone Grit Series, two other marine horizons are seen, with an obvious unconformity above (Fig. 5): this transgression increases southwards, cutting out the highest limestone in the Foxton Hall shore section, N. of Alnmouth.

The section at Shilbottle (Fig. 5) is wholly derived from records of bores and shaft sinkings now in progress. Evidence for the upper limestone is given by one bore only, but below this there is ample confirmation of the sequence. It is of interest to note that one of the coals about the Hazon Lee position is a 'parrot,' and no doubt represents the Lickar Parrot of Howick and Berrington. Correlations with the Tyne valley areas are best deferred until the intervening ground has been examined: all that need be said here is that the Cushat Limestone of Howick certainly represents the Little Limestone of the Tyne region,

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and that the Lickar Limestone is the Oakwood Limestone of that area.

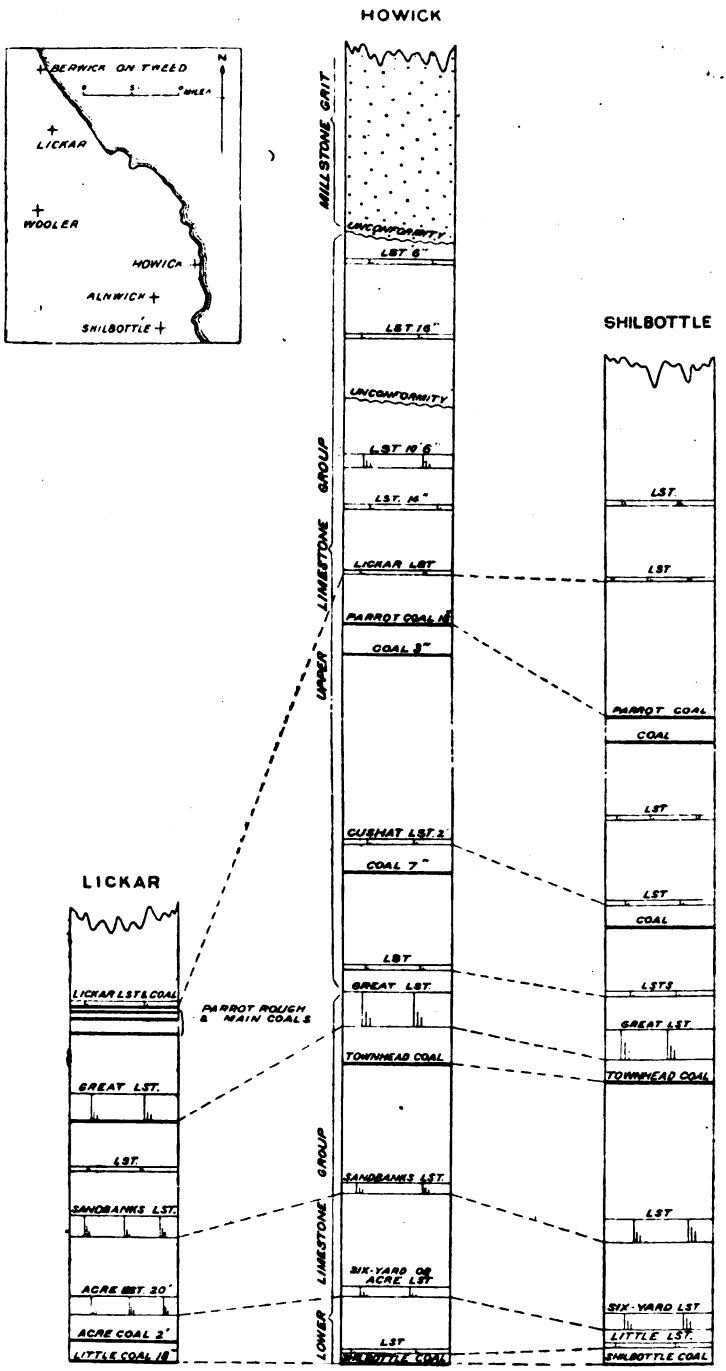

FIG. 5.—*Carboniferous Limestone Strata in North Northumberland.*

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Mr. Fowler and Mr. Maden are still engaged in revision of the Upper Limestone measures in the valleys of the Coquet and the Font: the few sections available are disconnected; the strata undulate considerably, and are much obscured by drift. Mr. Fowler has found a new outcrop of the Little (or Rothley) Limestone of the Tyne, N. of the Coquet, in the streams near Cockshot, but no definite statements as to the rest of the ground are desirable until the work is completed.

Between the River Wansbeck and the Tyne a workable coal, from 2 to 3 feet thick, is found below the Little Limestone. Several borings to this seam have been put down during the past two years in the Capheaton district, and again on the south bank of the Tyne, at Dilston. The cores were examined, and at the same time some revision work was done in the neighbourhood. The borings in both districts have provided a definite account of from 700 to 900 feet of strata, ranging from the Corbridge Limestone down to the Little Limestone Coal, a sequence not well known hitherto. The readings agree very well, although the two districts are 12 miles apart: they have led to some alteration, and several additions, to the maps concerned.

Coal Measures.—During the autumn, work was started on the Coal Measures in the vicinity of Newcastle. Mr. Maden took the area N. of the Tyne, while S. of the river Mr. Burnett began W. of the Derwent. The ground from the Derwent River to the Team valley is being revised by Mr. Anderson.

On the N. side of the city twelve coals or more have been wrought. They are distributed through some 900 feet of strata, and range from the Five-Quarter down to the Brockwell Coal. The ground is traversed by a large fault, down N.W., a continuation of the Ninety-Fathom Dyke, involving the Magnesian Limestone on the coast at Cullercoats. In old days the coals were wrought from the S. up to the 'dyke,' but not beyond, owing to the risk of encountering heavy feeders of water in piercing the fault-line. At the present time the relatively unworked area on the N. side is being actively exploited.

Underground extensions of the dolerite dykes seen on the surface at Walbottle (where it was wrought for road-metal) have been mapped both E. and W. In the workings of the Caroline Pit the dyke stops abruptly, reappearing again about 200 yards farther N. without any visible cause: similar phenomena are not unknown elsewhere, and may be due to the intrusion taking advantage of joint planes in depth.

The Kenton Sandstone, above the High Main Coal, is quarried for grindstones, as also is the freestone at Gosforth (Ouseburn). Fireclays associated with some of the coals are also worked to some extent, but none of them are of exceptional character.

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Mr. Anderson reports that between the Derwent and Team valleys the Productive Measures total about 700 feet, including 8 or 9 workable coals, and they extend down to the Millstone Grit. All the seams are coking coals, save the two lowest (the Victoria and Marshall Green coals) which are house coals. Practically the whole sequence can be seen in the Leap Mill Beck, which runs into the Derwent at Rowland's Gill. The coals seen there are constant over the whole area, the only notable change being in the Busty Coal, whose 4-inch ' Band ' increases eastwards to 30 feet. Faults are rare, the largest being 12 fms. down S., in the Byermoor, Andrew's House and Allerdene collieries.

The structure and sequence is thoroughly well known to all the companies concerned, but the nomenclature of the seams is distinctly confusing. While it is not surprising to find several names given to one and the same coal, even in this relatively small area, it is altogether more disturbing to find a particular name (*e.g.*, the Hutton, the Stone, or the Five-Quarter Coal) given to entirely different seams, and this even in adjacent properties : and in at least one case the name ' Five-Quarter Coal ' is given to two widely separated seams in a single shaft.

Glacial.—When revising the Tweed valley between Cornhill and Crookham, an extensive series of ' kettled ' gravels was noted lying on boulder clay. They are no doubt due to the melting of a considerable sheet of " dead ice " heavily laden with detritus. The ground is covered with irregular accumulations of dirty sand and gravel, interspersed with frequent " kettles," or shallow depressions without natural outlet. Over 50 of these were observed S. and S.E. of Cornhill, there being a particularly fine example at Campfield, half-a-mile S. of the village. The " kames " at Wark and S. of Pallinsburn House are apparently part of the same phenomena, and their heaps of unstratified and unassorted gravels may well be ascribed to the accumulation of surface detritus at the bottom of large crevasses, after ice-movement had ceased. There is evidence that the great Bradford " kame," S.W. of Belford, is of similar origin, as also may be certain mounds of dirty gravel noted by Mr. Maden in the Font valley near Roughlees.

The occurrence on Holy Island of two boulder clays, probably remnants of a single glaciation, was noted in last year's " Summary." They now prove to extend over wide areas in North Northumberland, from the Tweed valley, at least as far as the River Coquet. The lower clay, or true ground-moraine, seems to lie generally in hollows, and is often barely traceable on higher ground, or over projections of the underlying rock surface. Further sections of the ground-moraine have been noted on Holy Island, and on the N.E. side of the Island, a " boulder " of coarse sandstone

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or grit, fully 62 yards long, but no more than 2 feet thick, is exposed in a continuous section along the low cliffs. It lies several feet above the local rock-head, which hereabouts is a well-bedded dark shale. Adhering to the underside of this boulder is a strip of soft coal, which must have been frozen solid with the grit when the mass was torn off by the ice-sheet.

Mr. Dinham has observed traces of drift-filled pre-Glacial valleys, S.E. of Alnwick, and the Shilbottle ridge, E. of the village, is crossed by a fine overflow channel, more than a mile long, at Trobes Dene, between Longdike and Low Buston.[1]

In the Newcastle district Mr. Anderson reports the presence of a large pre-Glacial valley, hitherto unrecorded, which runs S.W. to join the well-known "Team valley washout" at Urpeth Hall. Boreholes along its course reveal a maximum thickness of 200 feet of sand and gravel, the surface-level now being 400 feet above O.D. at that particular point. Mr. Maden has noted that at Heaton a laminated clay is being wrought for brickmaking, beneath 20 feet or so of normal boulder-clay. Some contortion is observable near the top of the brick clay; its origin is still uncertain.

A "buried forest," was noticed 47 years ago on the foreshore at Howick, S. of Rumbling Kern. This is now covered by sand, but a fresh exposure is visible at the present time a mile farther S. at the mouth of the Howick Burn. The usual tree trunks (some still in their position of growth) of oak, birch, and alder, can be seen, along with hazel nuts. They rest in a peaty soil, in which small fresh water shells are occasionally found. This exposure is only visible at low tide.

(B)—SCOTLAND

Coalfield Revision

1. Ayrshire Coalfield

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Work was continued in Central and Northern Ayrshire and in the part of Renfrewshire which is included in Sheet 22.

Old Red Sandstone.—Mr. Simpson reports that on Tincornhill and the adjacent high ground the Lower Old Red Sandstone consists of sandstones sometimes massive, but more often flaggy and usually greenish-brown. The grains are angular,

[1] First noted by Dr. J. A. Smythe. See *Trans. Nat. Hist. Soc. Northumberland, etc.*, vol. iv. (1909–1913), p. 107, and Map No. 1 (Channel No. A 21).

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and obviously felspathic. Clay galls are common, and are often in layers parallel to the bedding planes. The general dip is to W.S.W. at a gentle angle, but false-bedding is sometimes very marked. The series includes a conglomerate, with well rounded pebbles of quartz and flint, which forms the summit of Blacksidend.

The same varieties of sandstone are present in Blackside, Auchinlongford, and Wedder Hills, mapped by Mr. MacGregor. In both areas the finer sediments have been hornfelsed by the action of igneous intrusions. This may be due to an underlying plutonic mass, continuous with that which rises to the surface in the Distinkhorn area farther north. In this district, numerous sills and irregular masses of intermediate and sub-basic type, and dykes of felsite and lamprophyre cut the sedimentary rocks.

In the burn at Burnhouse these sediments underlie the Upper Old Red Sandstone. The latter consists largely of yellow, or chocolate-coloured sandstones. They are very friable, and often decidedly calcareous. Interbedded with the sandstones are very green and brown marls; there are also frequent beds of nodular cornstone, and thin bands of conglomerate.

The two series are not seen in contact, but their dip is similar, both in degree and direction. The lithological difference, however, of the types makes separation easy; and in the overlying series the numerous intrusions and the hornfelsing which characterise the underlying sediments are both absent. It is clear that before the deposition of the Upper Old Red Sandstone, the lower series was invaded by igneous rocks, and subjected to a certain amount of erosion.

Near Auchmannoch, Mr. MacGregor has found that the types of Upper Old Red Sandstone rocks are much the same as those in the area farther south. Cornstones are here well developed, and are exposed in many disused quarries. These cornstones consist mainly of more or less horizontal bands of irregular calcareous concretions in a matrix of impure sandstone. In the best limestones the whole rock consists of such concretions, with some cherty material. A very fine example is seen in the Old Craigleith quarry, east of Lawdyke, where the longer axes of the concretions show a tendency to be vertical.

Calciferous Sandstone Series.—South of the River Irvine the volcanic group in this series is thin or absent. The underlying Cementstone Group may also be absent, but in the areas mapped this year, some miles to the north and to the east of Sorn, it is typically developed.

The base of the Cementstone Group was noted by Mr. Simpson in the burn-section east of Tincornhill at a point west of Burnshield. It is marked by a bed of brown marls containing fish scales and entomostraca. This bed occurs only 10 feet

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above a cornstone of Upper Old Red Sandstone type, and is succeeded by grey flaggy micaceous sandstones and thin cementstones, one of which is conglomeratic. The passage-beds between the Upper Old Red Sandstone and the Cementstone Group have also been studied by Mr. MacGregor, in the Auchmannoch neighbourhood, where several burn-sections show an apparently conformable passage between the two groups. In its basal part the Cementstone Group contains (1) red marls, which alternate with greenish marly shales, and (2) thin bands of flaggy, sometimes micaceous sandstone, which replace the usual thin bands of cementstone. These layers often contain green clay galls; they commonly show ripple-marks and sun-cracks. Another feature of the base of the series is (3) the development of bands of conglomeratic limestone, made up of rounded fragments of cementstone. These fragments were probably derived from previously solidified cementstone, and like the sun-cracks and ripple-marks, point to extremely shallow water conditions.

The overlying volcanic group is very thin in this part of Ayrshire, and its outcrop cannot always be traced. On the north bank of the River Ayr, however, near the farm of Hole, Mr. Simpson observed a fossiliferous limestone belonging to the Carboniferous Limestone Series resting on an altered lava. The type of alteration resembles that which has affected some of the Millstone Grit lavas in north Ayrshire. About 10 feet of lava is seen; the lower part is brown or greenish in colour, and platy, owing to the parallel arrangement of felspar crystals, which, as in the Millstone Grit lavas, is not a genuine flow structure. Towards the top of the flow contemporaneous weathering has altered the rock into a material extremely like the Bauxitic Clay of Northern Ayrshire. The lower part of this clay contains grains of sphaerosiderite, but the upper part (twelve to sixteen inches thick) is without iron carbonate, and pure grey or white in colour.

Carboniferous Limestone Series.—Mr. Anderson has mapped an area of Carboniferous Limestone about three miles to the south of Galston. The central division, or Limestone Coal Group, here contains a coal which in one place is 2 ft. 6 in. in thickness, and locally, has been opened up in old crop workings.

Another small area of rocks belonging to this group is intersected by Burn o' Need, about a mile to the west of Blackside. There are old coal workings close to the burn. The 'Statistical Account of Scotland' states that the coal was 5 ft. in thickness.[1] Mr. MacGregor reports that a coal is now seen which is between 1 ft. 6 in. and 2 ft. in thickness, but it may be a short distance above that which was formerly worked.

[1] Vol. xx, 1798, p. 138.

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Mr. Simpson has found that the limestones seen in the River Ayr, above Sorn, include representatives of both Upper and Lower Limestone Groups. Several seams of coal are exposed in natural sections in the Limestone Coal Group, but only one of them, which is three feet in thickness, seems likely to be workable. The coals formerly worked near Sorn village are not now visible.

In the northern part of one-inch Sheet 22, the stratigraphy of the Lower Limestone Group, and the Calciferous Sandstone sediments, has already been fully investigated.[1] These strata are there well developed, and include the following beds:—

Hosie Group, consisting of blaes with 3 or 4 thin limestones, and a thin fireclay	Up to 17 fms.
Dockra (Hurlet) Limestone and Coal	„ 7 „
Upper Calciferous Sandstone sediments consisting of fireclays and marls with from 1 to 4 limestones. Volcanic detritus at the base overlies the Calciferous Sandstone lavas	„ 30 „

In the south-east part of the one-inch Sheet, where the above strata are much curtailed by overlap on to older rocks, the correlation of the various beds from place to place, and with those of the area to the north, has been carried out by Mr. Richey.

At Stewarton, the Upper Calciferous Sandstone sediments are almost entirely overlapped by the Dockra Limestone. The latter is itself greatly curtailed east-north-east of Stewarton, and is only 5 feet thick, in the Annick Water, west of Broadland. Farther eastwards, at Laigh Clunch, the Dockra is entirely absent, and the lowest Hosie limestone is the first marine position met with above the beds of volcanic detritus. This can be correlated with certainty with the first Hosie limestone found above the Dockra in the Annick Water exposure by a distinctive fossil bed immediately above it.

The Dockra Limestone in the Stewarton district, and generally throughout this one-inch Sheet, has a peculiar, uneven, bleached top, which is often pierced by rootlets and overlain by a thin bed of greenish marl or fireclay. It has also been recognised by this peculiarity in the Galston district. North of Galston the limestone is mixed with volcanic ash, beds of which are also found below the limestone. This denotes continuance of the volcanic activity of Calciferous Sandstone times in this district to a comparatively late date.

The Hosie Group near Stewarton includes three limestones, but north of Galston only the two upper limestones of this series

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[1] P. Macnair, 'The Hurlet Sequence in North Ayrshire,' *Trans. Geol. Soc., Glasg.*, vol. xv, 1914, p. 200.

R. G. Carruthers and J. E. Richey, 'The Lower Limestones of Renfrewshire and North Ayrshire: a comparison and correlation,' *ibid.*, p. 249.

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were found. These are exposed in the Hag and Polbaith Burns as well as at Inchgotrick, south of Kilmarnock.

The Top Hosie Limestone is associated in the Stewarton district, and also at Inchgotrick, with blaes containing *Posidonomya corrugata*. This is the characteristic fossil of the Top Hosie horizon which has been traced over a wide area by Prof. Macnair.

At Inchgotrick, this limestone is a thin cement-like irony band with few fossils. A similar thin band is found in this position in the Polbaith Burn and near Wellhill, north of Galston, where it is overlain by a band of ironstone succeeded by a coal seam. This succession furnishes a good means of distinguishing the horizon in the Galston district. The Top Hosie can thus be recognised in Burn Anne, near Cessnock Castle, where certain strata have long been known to be absent at the base of the Carboniferous system. Beds of limestone almost immediately overlie the Upper Old Red Sandstone, which includes a cornstone. The Calciferous Sandstone lavas and cementstones are entirely absent. The extent of the unconformity has now been determined as the limestones include only the two upper bands of the Hosie Group. A thin conglomerate with small pebbles of chalcedony and of cornstone marks the unconformable base of the Carboniferous Limestone.

Millstone Grit.—Recent work in North Ayrshire has shown the constancy and extent of the Millstone Grit volcanic series. In the Gailes bore (half-a-mile south-east of Gailes Station) the lavas are 90 fms. in thickness. This indicates that they might be expected to have an extensive outcrop. Mr. Anderson has found that they are present at the surface for quite a mile to the north and east of Barassie, and form a broad belt running east through Symington, whence they extend in a narrowing strip along the northern margin of the Mauchline basin. In part these lavas had previously been mistaken for intrusive rocks. The Craigie Hill mass, which borders the lava area, is an intrusion, It extends as far as Catcraig Quarry, and is intersected by minor intrusions of a fine-grained basic rock with a distinctly glassy character.

Coal Measures.—Areas of Coal Measures have been mapped by Mr. Simpson to the west of Old Cumnock, and by Mr. Anderson and Mr. Eyles in the neighbourhood of Dundonald and Prestwick. The Old Cumnock area is mainly drift-covered, but a section of productive Coal Measures is seen in the River Lugar between Old Cumnock and Lugar village. Most of the workable seams crop out on the banks, but were formerly rather poorly exposed. During the strike in 1921, however, most of the outcrops were opened up, and the clearer exposures have enabled many corrections to be made in the published map.

The Prestwick area is also drift-covered, and practically the only rocks exposed are igneous intrusions, as in the Dundonald and Clevance Hills. These consist of a thick sill of teschenite

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dolerite, which is in a higher position than the Coal Measures to the north-west, west, and south. This sill may also form the promontory which protects the harbour at Troon. Its horizon is not accurately known, but a coal which was worked on a small scale near Colleman in the underlying sediments is supposed to have been the Splint or Hurlford Main.

Several unrecorded sills and dykes have been mapped by Mr. Eyles between Prestwick and Tarbolton. A thick sill exposed in a stream bed 600 yards E.N.E. of Townhead, near Monkton, shows much vertical variation.

Mauchline Volcanic Group and New Red Sandstone.—A considerable area of these rocks has been mapped by Mr. Simpson near Ochiltree, where an intercalation of sandstone occurs in the volcanic series, probably near its base. Underneath the sandstone is a thick ash, which may form the base of the volcanic group. The junction of the latter with the underlying Barren Red Coal Measures, is nowhere seen in this district.

Glacial and Post-Glacial.—Further occurrences of shell fragments in boulder-clay have been noted in the Sorn district by Mr. Simpson.[1] The highest occurs in a stream section 100 yards north of Burnshield (east of Tincornhill, 700 feet above sea-level).

A mile farther west, near Westown, very finely glaciated surfaces are visible at the border of a quarry. The striae occur in sets which run W. 15°–25° N., W. 35°–40° S., and S. 10° E., but in no case could the direction of ice-flow be determined. On the moor, west of Burnhouse, there are crossing striae which may correspond to the first and last of these directions.

Glacial overflow channels have been found by Mr. Anderson to cross the ridge of the southern part of the Dundonald Hills, near Clevance and Harpercroft, and have an eastern drainage. This suggests that at one time the ice pressed against these hills from a western direction.

In the coastal area to the south of Troon, Mr. Eyles has mapped a raised beach plain at the 35 or 45-ft. level. Raised beach material also exists at higher levels, and chiefly just below the 100-ft. contour. It usually consists of a thin gravel capping, which may often be seen to overlie boulder-clay. A good section exposed in the burn south of Brieryside, is :—4 feet coarse gravel, over 4 feet laminated reddish brown sand, with large rounded boulders, and fine pebbly layers, resting on laminated sandy clay; base not seen.

These beds appear to be relics of the 100 or 110-ft. platform of marine alluvium of northern Ayrshire, but the deposit is local.

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[1] See 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 78.

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2. Central Coalfield

Muirkirk District

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Mr. Wilson continued the revision of the much folded and faulted Muirkirk Coalfield. In the 'Summary of Progress for 1921' mention was made of the important fault forming the northern margin of the field; this has now been proved to extend continuously from the coast near Girvan to beyond the head of the Pockmuir Burn. To the south and east the boundary between the Carboniferous rocks and older formations is in some places a fault, but elsewhere the Carboniferous rocks rest conformably on the Upper Old Red Sandstone. The average width of the coalfield is about one and a third miles. The strata are thrown into small folds with a general N.N.E. trend, and are traversed by numerous faults with directions varying from W.N.W. to E.N.E. Many dolerite dykes occur, some of which accompany the lines of faulting.

Upper Old Red Sandstone.—Along the southern margin of the area the base of this series is a coarse conglomerate consisting mainly of rounded pebbles of Silurian greywacke and a few quartzites. It is of a reddish or greenish colour, and is often characterised by much calcite-veining in the matrix. A thin cornstone occurs a few feet above the conglomerate. On the northern boundary, however, the conglomerate has not been noticed, but one or two thick bands of cornstone occur just above the base of the series.

Calciferous Sandstone Series and Lower Limestone Group.—The Calciferous Sandstone volcanic series which is widely developed in North Ayrshire does not occur in the Muirkirk area. Along the northern edge of the area a thick bed of variegated sandy marls with bands of cementstone, is found overlying the Upper Old Red Sandstone. This Cementstone Group has been proved to extend from the Mossy Burn in the west, to Monkshead, above Glenbuck, on the east. Along the southern boundary, however, the Cementstone facies has not been noticed, and the limestone-bearing strata are found to rest directly on yellow sandstones, which pass down gradually into the Upper Old Red Sandstone. As yet it has not been possible to draw a line between the Calciferous Sandstone Series and the overlying Lower Limestone

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Group. The general succession, which is much the same on both sides of the area, is as follows :—

MACDONALD -	Limestone and limy blaes (very fossiliferous)	20 to 30 ft.
	Strata (sandstone and blaes) - - -	5 „ 10 „
	Limestone - - - - - - - -	9 in.
	Coaly blaes and fireclay - - - -	5 ft.
	Limestone (crinoidal) - - - - -	1½ „ 2 „
	Pyritous nodular blaes - - - -	10 „ 15 „
	Fakes - - - - - - - -	2 „ 8 „
	Black blaes (sometimes variegated with red streaks).	10 „
	Sandy fireclay and sandstone - - -	3 „ 9 „
HAWTHORN -	Nodular limestone (corals and *Productus*) -	1 „ 9 „
	Limestone and limestone blaes - - -	up to 12 „
	Small gap - - - - - - - -	? 6 „
	Limy blaes and limestone bands - -	up to 12 „
	Sandstone - - - - - - - -	? 40 „
WEE -	Limestone - - - - - - - -	2 „ 3 „
	Sandstone.	

Cementstones (on the north margin only).

The Wee Limestone usually yields a few fossils. In the Stottencleuch Burn and above Monkshead on the northern side of the area, it is creamy and nodular. Along the southern margin, however, it is grey and sandy. Owing to the fact that the complete sequence between the base of the Hawthorn Limestone and the underlying limy blaes with limestone bands has not yet been seen, it is impossible to state whether the latter represent a separate limestone horizon or are simply the lower portion of the Hawthorn. The top of the Hawthorn Limestone is often exposed. It can be recognised by its nodular character, and by the presence of large *Productus*, and masses of *Lithostrotion junceum* up to 2 feet in thickness. The appearance of the bed suggests that it represents a coral reef, which was gradually rising from the sea and approaching to land conditions. The occurrence of filled-in sun-cracks in the immediately overlying sandy fireclay adds strength to this hypothesis. It is not yet possible to correlate the Hawthorn with any of the limestones of Ayrshire or the Central Coalfield; it has, however, certain characteristics, such as the nodular top, which suggest its identity with the Dockra of Ayrshire. An excellent section of the coral reef is to be seen in the old quarries near the Ashaw Burn.

Some of the thin limestones which occur between the Hawthorn and the Macdonald may represent the Lower Hosies of Ayrshire, and no doubt the Macdonald is equivalent to the Upper Hosie Limestones. Until the fossil evidence is more complete it is, however, unwise to make any definite correlations.

The Limestone Coal and Upper Limestone Groups.—The section of the Limestone Coal Group in the Auldhouse Burn shows that the basal portion consists mainly of shale and the upper portion, in which the coal seams occur, of sandstone. Farther west, in the small burn above Wellwood Pit, the shale and associated ironstone which overlie the Macdonald Limestone are seen to contain *Lingula* and a few other fossils.

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The members of the Upper Limestone Group are well-exposed in the Garpel. Five limestones occur. The Index is not now exposed, but its position is marked by an old quarry. In other parts of the area it is often readily recognised by the presence of numerous shells of *Productus latissimus* in the top part of the seam. A sandy limestone with a few shells occurs a short distance above the Index. The middle limestone is about 6 ft. thick, massive, and is exposed under the old bridge on the road to Wellwood Pit. A little farther down-stream, about 30 feet of highly fossiliferous limy shales with bands of limestone occur. They are underlain by black fossiliferous blaes and parroty blaes, and overlain by a false-bedded sandstone, 40 feet thick. This in turn is followed, in upward succession, by a coal and by the overlying Blue Tour Limestone. The latter bed is well-exposed under the bridge on the G. & S.W. Railway line to Ayr.

Millstone Grit.—The massive bed of sandstone which occurs a few fathoms above the Blue Tour Limestone is probably of Millstone Grit age. A bed of fireclay is exposed, on the down-throw side of a fault, in the small burn near the top of Hawkshaw Plantation. It is about 10 feet in thickness and is usually of a reddish colour. Certain grey bands associated with the seam have many characteristics of the Ayrshire Bauxitic Clay.

Igneous.—In the small burn, above Wellwood Pit, a felsite dyke which is intruded into Lower Old Red Sandstone rocks, is cut off by a fault which brings down the Macdonald Limestone directly against the dyke.

Glacial.—Great spreads of glacial sand and gravel are found on both sides of the Ayr valley near Muirkirk. They occasionally occur in the form of mounds, but terrace-like formation is the more common. An excellent section in a sand mound is to be seen in the pit, on the railway side, 200 yds. south-west of Auldhouseburn Pit. The material is mostly fine-grained, with occasional pebbly and coaly layers. It is used for pig-iron casting-beds.

COALBURN DISTRICT

Mr. Ross continued the revision of the Downtonian and Lower Old Red Sandstone rocks to the north-west of the Douglas coal-basin, and the Carboniferous sediments in the Lower Nethan and Scots Burn valleys.

Downtonian and Old Red Sandstone.—On the north side of the valley of Kype Water, 160 yards S.W. of Townend Farm an exposure was noted of the Quartzite Conglomerate forming Zone 3 of the Downtonian Series.[1] The conglomerate is here overlain by red sandstone flags dipping north at 18 degrees. This indicates a slight extension northwards of the outcrop of the upper band of the conglomerate. A recent exposure of

[1] 'Silurian Rocks of Great Britain,' vol. i Scotland (*Mem. Geol. Surv.*), 1899, p. 68.

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purplish micaceous sandstone of Lower Old Red type dipping east at 15 degrees, was noted 180 yards E.S.E. of Townend Farm. This serves to define more accurately the course of the great north and south fault which separates Downtonian rocks from the Old Red Sandstone. On the west side of this fault, from a point about 200 yards west of Juanhill, the directions of dip of the Downtonian rocks radiate outwards, north-west, north, and north-east, at angles from 15 to 20 degrees, showing these to be folded in an anticline pitching gently north. The axis of the fold passes southwards through a point about 400 yards west of the confluence of Hareshaw Burn and Kype Water, the dips of the flaggy shales and sandstones of Zone 1 of the Downtonian Series exposed in the bed of the former varying from N.N.W. to N.W. at angles from 10 to 20 degrees, while similar strata appearing to the east in the bed of the latter dip N. and N.N.E. at angles from 5 degrees to 15 degrees. From this point the axis swings slightly east of south and is truncated by the fault to the west of Auchrobert Snout. Here the Quartzite Conglomerate band reappears to the east of the fault and its outcrop can be traced in a broad crescent eastwards through Lower Waterhead and then southwards, passing just east of Cleuchhead.

Pre-Carboniferous Igneous Rocks.—A set of igneous intrusive rocks varying in type from dark red coarse-grained hornblende-felspar-porphyry to salmon-pink fine-grained quartz-porphyry appears above the Quartzite Conglomerate of Zone 3, good exposures being seen just south of Goslington, on Auchrobert Hill, and on the heights between North and East Brackenrig. Where their relations can be determined, these intrusions are sill-like in form, either parallel with the bedding of the sediments or cutting them at low angles.

Carboniferous.—The re-examination of the faulted belt of Carboniferous rocks in the valley of the Scots Burn and in the Lower Nethan was continued. In the small western tributary of the former, 500 yards S.W. of Stockhill, good exposures occur of white and red sandstones and grits with subordinate marly bands dipping N.E. at angles from 18 to 30 degrees. These appear to rest unconformably upon the flaggy red sandstones of Lower Old Red type exposed a few yards farther west dipping east at about 40 degrees, and to represent shore deposits of Lower Calciferous Sandstone or late Upper Old Red Sandstone age. Farther east, in Scots Burn, 350 yards S.S.W. of Burnside, occurs a band of variegated pebbly conglomerate about 18 inches in thickness containing pebbles of chert, quartz and red sandstone.

To the east of this exposure the strata are of more normal Calciferous Sandstone aspect, with occasional bands of cornstone, and, near the top, several thin bands of limy marl with marine organisms. In the Lower Nethan north-west of Dalquhandy Farm, are exposed two thick bands of cornstone with green and red marl between, dipping east at 25 degrees. These are comparable with the "Foul" or Nodular Limestone recorded

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elsewhere in the district several fathoms below the "Big" Limestone of Auldton and Auchren.

The "Big" Limestone of Auldton, which is characterised by the presence near its top of *Productus giganteus* (the typical form) is exposed in the Nethan 400 yards north of Old Stockbriggs. Here it dips N.N.E. at 20 degrees, and about 160 yards downstream is an exposure of the "Wee" Limestone of Auldton about six feet thick, with crinoidal shales above and an eight-inch coal below. About 200 yards farther downstream, appears an outcrop of limestone and fossiliferous shales about 12 feet thick containing *Ambocoelia urei*, which is common at the Blackhall Limestone horizon, and found elsewhere in the district in the "Main" Limestone of Coalburn. These limestones apparently follow upwards in normal sequence. The "Big" Limestone reappears in the Logan Water S.S.E. of Whiteside, just east of the fault bringing it down against the Lower Old Red Sandstone to the west, and from this point it follows the course of the Nethan immediately east of the fault for about three quarters of a mile. An exposure of the "Wee" Limestone about 5 feet thick, with a six-inch coal below, was seen about 30 feet above the "Big" Limestone in the steep east bank of the Nethan west of Auchlochan House. The next exposure of the "Big" Limestone occurs in the east bank of the Nethan just east of Auchlochan Bridge. From here downstream to the point where the boundary fault crosses the Nethan S.W. of Gateside, the strata appear to belong mainly to the Lowest Division of the Carboniferous Limestone Series, with the exception of a small faulted inlier of Lower Old Red Sandstone unconformably overlain by Calciferous Sandstone sediments exposed in the bed of the Nethan east of New Trows.

Four hundred yards W.S.W. of Auchlochan Bridge, a few yards above the weir across the Nethan, a well-marked W.N.W.–E.S.E fault brings down Upper Limestone strata. From this point to Auchlochan Bridge where another fault with S.S.E. downthrow cuts it out, the Index Limestone is repeated three times in the bed of the Nethan in a sharp anticline and syncline. In the core of the syncline appear two outcrops of a higher limestone about 4 feet thick with a thin coal below it. Another outcrop of the Index Limestone was noted in Johnshill Burn, 100 yards downstream from the public road. The following is a slightly generalised section of the Index Limestone from the outcrops west of Auchlochan Bridge :—

Limy blaes, faky at top	15 ft. seen.
Crinoidal limestone containing *Productus latissimus* at top	1 ft. 6 in.
Crinoidal shale	9 in.
Massive dark blue limestone, ochreous on surface, weathering in rectangular blocks	4–5 ft.
Rooty fakes and fireclay with coaly blaes 6 inches from top	15 ft. seen.

Post-Carboniferous Igneous Rocks.—A fine-grained basic dyke probably of Tertiary age, about 30 ft. wide, crosses the bed of the Kype Water, just north of the Kype Reservoir dam, and its

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continuation to the south-east is exposed in Logan Water, 500 yards east of Dunside. A basic dyke passes about 500 yards west of Dalquhandy Colliery, and accounts for the burnt outcrop of the Ell Coal running near it for about 300 yards northwards.

Glacial.—A notable series of sand and gravel mounds extends on the high ground just above the 900-ft. contour from half a mile N.E. of W. Craighead, across the Upper Nethan valley S.E. to Stockhill. Eastwards from there the country is thickly covered with stiff greyish brown boulder-clay. Associated with these gravel deposits is a set of shallow glacial drainage channels which trend S.S.E. on the heights around Greenfaulds, while their continuations in the high ground east of Stockhill tend to swing round S.E. towards the Coalburn valley. They are well defined, and cut sharply into the boulder-clay to a maximum depth of about 35 feet. The lowest and best marked of them is now occupied by the railway from Dalquhandy Colliery.

STRATHAVEN

Revision of the area of Calciferous Sandstone lavas, begun by Mr. Dinham and reported in the 'Summary of Progress for 1915,' has been continued by Mr. Phemister, who finds that the lavas are olivine-basalts of a variety intermediate between the Dalmeny and Dunsapie types. The variations are considerable, but no typical Markle or Craiglockart types are found, and similarly, classification as porphyritic or non-porphyritic is in some cases quite arbitrary. Amygdaloidal varieties are common, and spheroidal weathering is frequent. Other flows of the same types are comparatively fresh. Terraced features due to flows are rare, indistinct, and of very small extent, and a continuous covering of boulder-clay, gravel, or peat combined with the lack of outstanding characteristics in the lavas themselves, precludes accurate correlation over any considerable area.

On the right bank of the Calder Water, just below its junction with the Little Calder, there is a small exposure of typical yellow weathered trachyte. It is probably a flow, but its relations to the basalts are not seen. In the same neighbourhood there are two bosses, one of albite-porphyry, which forms a "craig" on the east margin of Mossmulloch, and another of mugearite(?) forming the small hill called the Law.

CLACKMANNAN

Mr. Read has continued the re-mapping of those parts of the volcanic rocks of Lower Old Red Sandstone age of the western end of the Ochils which fall within the six-inch sheets of the Clackmannan Coalfield.

The steep face of the Ochils between Menstrie and Bridge of Allan is formed by a series of conglomerates, agglomerates, and andesite lavas which dip gently northwards. As mentioned in last year's 'Summary of Progress,' the volcanic pile is cut up into blocks by powerful N–S faults. A sequence of some thirty

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lavas, together with intercalated conglomerates and agglomerates, has been established. Intrusive rocks in this area are limited to (1) a few narrow, much decomposed dykes of intermediate or basic composition, (2) a conspicuous blotchy pink felsite seen immediately west of Dumyat, (3) several small masses of basic rock occurring above Blairlogie, and (4) the glassy hypersthene-andesite of Airthrey described by Dr. J. S. Flett[1] and Prof. W. W. Watts.[2]

The Carboniferous rocks lying between the Blairlogie Ochils and the River Forth are concealed by the Carse clays of the 50-ft. Raised Beach. What appears to be a new section of Millstone Grit has been found in the River Devon between its junction with the River Forth and the village of Cambus. Here, at low tide, fireclays and sandstones of Millstone Grit type are seen dipping gently N.N.E.; according to bores at Cambus the horizon is low down in the Millstone Grit. No trace was found of the "Mountain Limestone" seen by Robert Bald[3] a century ago "in the Devon near Cambus"; if Bald's identification as limestone of the rock seen by him was correct, it is possible that he was dealing with one of the thin marine bands in the Millstone Grit.

Mr. Haldane extended the revision of the Clackmannanshire Coalfield to the north-east of Alloa along the valley of the River Devon from Tillicoultry to Dollar and Blairingone. The area is bounded on the north by the great Ochil Fault.

Coal Measures.—The western portion of the area in the neighbourhood of Tillicoultry consists of Coal Measures strata forming the eastern side of the Devon basin. East of this the region appears to be much faulted and is dotted over with long-abandoned shafts. A few sections are seen in the small streams to the south of the Devon, but these are poor and the horizon of the strata cannot be identified with certainty. The Alloa Cherry Coal, dipping north, crops out near the foot of the Bessie Glen, south-east of Tillicoultry, and reappears at the surface on the high ground to the south. In the Melloch Glen, 1,100 yards east of Bessie Glen, another outcrop of the same seam occurs.

Two small isolated basins of Coal Measures occur at Dollar and Blairingone. The section of the eastern portion of the Dollar field at Lawhill is reported to extend from about the position of the Nine-foot Coal down to the Coalsnaughton Main; (Vertical Section 4, Sheet 5. Geol. Survey, Scotland, 1877), but no recent information is available and it is not known if there are workable seams below the Coalsnaughton Main as in the Alloa and Clackmannan areas. This also applies to the Blairingone basin where coal workings were in progress nearly a hundred

[1] J. S. Flett, 'A Hypersthene-andesite from Dumyat (Ochils),' *Trans. Edin. Geol. Soc.*, vol. vii, 1899, p. 290.

[2] W. W. Watts, in Sir A. Geikie's 'Ancient Volcanoes of Great Britain,' vol. i, 1897, p. 276.

[3] Robert Bald, 'The New Statistical Account of Scotland,' vol. viii, 1845, p. 24.

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years ago. A fireclay about three fathoms below the Coalsnaughton Main was mined about the years 1906–7. West of the town of Dollar, the coals have not been proved though it is likely that the seams in the Lawhill area extend west for some distance.

Millstone Grit.—In this neighbourhood the Millstone Grit appears to be thinner than in the Clackmannan district. Data are scanty, but an estimate of the thickness around Vicar's Bridge and Lawhill gives 115 fathoms compared with 150 fathoms near Clackmannan. In the neighbourhood of Sheardale House a large N.W. fault brings the lower beds of the Millstone Grit against Coal Measures strata. Sections in Byles Cleugh Glen and Rackmill Glen show a limestone taken as the equivalent of the Castlecary Limestone at the base of the Millstone Grit.

Two miles east of Dollar at the Vicar's Bridge the Devon flows through a rocky gorge, but the banks are thickly wooded and the section is much obscured by undergrowth and screes. In the vicinity of the bridge there are numerous refuse heaps and a few old mine openings to an ironstone formerly wrought for the Devon Ironworks. The ironstone is probably some 40 fathoms above the Vicar's Bridge Limestone but no records are available. About 250 yards east of the bridge is the Vicar's Bridge Limestone which has been extensively wrought in the past, and is considered to represent the Castlecary or Levenseat Limestone. As far as can be seen now it consists of about five feet of limestone and calcareous sandstone with a sandstone pavement and roof.

Carboniferous Limestone Series.—East of this limestone, strata of Carboniferous Limestone age are seen for about 350 yards until cut off by a large S.E.–N.W. fault which is probably a branch of the main Ochil Fault. On the east side of this fault, near Arndean, there is an intrusion of dolerite about 60 yards wide, much weathered and veined with calcite. The sediments on the east side of the dyke are much baked and disturbed, but farther east they pass downwards through a Cementstone facies into Upper Old Red Sandstone.

Glacial and Recent.—Boulder-clay covers most of the area south of the Devon valley. No glacial striae have been noticed. North of the Devon the boulder-clay is obscured or mixed with screes and hill wash from the south face of the Ochils. Just east of Tillicoultry a prominent series of sand and gravel mounds projects into the valley. The Cunninghar sand pit is situated in one of these mounds and shows a good section, over 50 feet high, of well-bedded alternating layers of sand and gravel. The beds dip to the east and north-east at angles of 8 to 10 degrees and false bedding is frequent. Much of the sand is very fine-grained, buff coloured, with coarser lenticular layers, while the gravel, in bands up to 10 feet thick, is composed of well rounded pebbles of igneous rock derived from the Ochil Hills. Occasionally there are thin bands in the gravel composed of fragments of coal with very much smaller pebbles of igneous material. This series of

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kames stands out boldly across the valley of the Devon which is here constricted to a narrow passage between two sandy spurs. An area of sandy gravel extends for nearly two miles along the north of the valley from north of Tillicoultry to east of Harviestoun Castle. Another expanse stretches east from Dollar and along both sides of the Devon.

The River Devon flows in a winding course through an extensive plain of alluvium west of Vicar's Bridge. This is interrupted by the alluvial cones upon which stand Dollar and Tillicoultry, and also by the kame at Cunninghar.

West of the kame, the alluvial flat merges into the Carse clays of the 50-ft. Raised Beach, the margin of which may be traced at a few places near Tillicoultry. Traces of the 100-ft. Raised Beach are occasionally seen here and also along the valley towards Dollar. Just west of this town where the alluvial cone merges into the flat there is a deposit of fine red laminated brick-clay similar to those found east of Alloa and north of Clackmannan. This deposit near Dollar where the clay was formerly wrought is probably a relic of the 100-ft. Raised Beach.

3. West Highland District

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Lewisian Complex: Tiree

The mapping of Tiree has been completed during the past field season.

Topographically Tiree falls into three divisions, separated by blown sand. Mr. MacGregor mapped the northern half of the western area, and Mr. Simpson its southern half. Mr. Eyles mapped the central area, with the exception of the Gott Bay para-gneisses which had previously been mapped by Mr. Bailey.

Orthogneisses.—Three varieties are recognisable :—

(1) Grey biotite-hornblende-gneisses.
(2) Black hornblende-schist.
(3) Pale grey, pink or red granite-gneisses.

(1) This is the prevalent type and is in the main a well-foliated quartz-felspar-hornblende rock in which biotite is usually present and sometimes conspicuous.

(2) The black hornblende-schist is much more basic than the foregoing. It consists essentially of hornblende, with a variable proportion of felspar and sometimes a little biotite; garnets are often present but their distribution is not uniform. This type is usually finer-grained than the grey gneiss and its banding is less conspicuous. Coarse-grained types occur, however,

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sometimes approaching a pegmatite. The black hornblende-schist is widely distributed. It is intercalated in the grey gneiss in thin streaks and lenticles, and in continuous bands, often of considerable breadth. Occasionally the bands of black hornblende-schist are transgressive to the grey gneiss.

(3) The granite-gneiss is not always easily distinguishable from the grey gneiss, except where it has a pink or red colour. Typically it is a quartz-felspar-rock with little hornblende, and it is usually finer-grained than the grey gneiss and less conspicuously banded. It has been recorded only from the central and eastern portions of the island.

Pegmatite.—Coarse felspathic pegmatites, often very thick, are common. Two varieties are recognisable, one pink and the other grey. The former is possibly connected with intrusions of granite-gneiss.

Paragneisses.—Mr. Eyles reports an isolated occurrence of rocks similar to those of Dun Gott.[1] They occur on the south-west side of Vaul Bay forming two skerries parallel with the shore. The larger skerry is 200 ft. wide and consists of rusty weathering pyritous calc-silicate-rock, biotite-garnet-schist and graphite-schist, with seams of magnesian marble. Mr. Bailey has also mapped a few feet of impure marble and calcareous schist, surrounded by granite-gneiss, in the extreme east of Tiree, on the coast just north of Eilean Liath; and Mr. Eyles a very small outcrop of similar rock surrounded by grey gneiss, at the south end of Loch Riaghain.

Garnet-Gneiss.—Mr. Simpson records two bands of garnet-gneiss which is probably paragneiss. The largest is about a quarter of a mile in breadth and occurs at the south end of Hynish Bay. It varies from coarse garnetiferous biotite-gneiss to garnet-biotite-granulite. A second band occupies a narrow strip of country stretching from the west side of Loch a' Phuill to Moss. Mr. MacGregor reports a further exposure of similar rocks just west of Loch Bhasapoll. In association with the Loch a' Phuill outcrop, Mr. Simpson found a strip of rock rich in magnetite (*see* p. 105). This grades from an almost pure magnetite rock into garnet-biotite-gneiss.

Tiree Marble.—Marble from Tiree, apart from the thin seams mentioned above, has long been well known. A. K. Coomaraswamy has described the chief occurrences in considerable detail.[2] Two varieties are found, distinguishable macroscopically by their colour. The pink " coccolite " marble, so familiar in museums, occurs in considerably less bulk than the greyish white type, which is also pyroxene-bearing. All previously described localities for both types are in the neighbourhood of Balephetrish Hill; Mr. MacGregor records an additional small exposure of the pink type about 5 miles away on the west coast

[1] ' Summary of Progress for 1921 ' (*Mem. Geol. Surv.*), 1922, p. 104.
[2] *Quart. Journ. Geol. Soc.*, vol. lix, 1903, p. 91 *et seq.*

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between the north-east end of Eilean Ghreasamuill and the mainland.

The marbles of the Balephetrish district are of unusual interest, both in regard to their texture, and to their field relationships.

Good contacts of marble and gneiss may be seen, both in the quarry on the west side of Balephetrish Hill, and on the shore to the west. In each of these localities Mr. Bailey and Mr. Eyles found that relations of the marble to the gneiss surrounding it are those of an intrusive rock. In the quarry, the pink marble is seen to cut sharply across lines of movement and flinty crush-bands in the gneiss, while on the shore the marble trangresses crushed and folded gneiss, and includes fragments of material which in some cases can be matched in the neighbouring orthogneiss. On the south end of the shore exposure a conspicuous crush-line occurs in the orthogneiss bordered by thick lines of black flinty crush-rock. The marble seems to have extended a tongue along this dislocation and a renewal of crushing has involved this tongue, with the development of a flinty textured grey limestone crush-rock (Coomaraswamy's mylonized limestone).

Flinty Crush-Rock.—Veins and bands of black, or occasionally green and epidotic, flinty crush-rock are common in Tiree, west of Gott Bay, and are more numerous than those described from Coll last year.[1] Mr. MacGregor records that in the north-west end of the island a crush-belt, some 150 yards broad, crosses from coast to coast in a north-easterly direction from a point 300 yards south-east of Eilean Ghreasamuill on the west to Rudha Port Bhiosd on the north. The strike of the gneiss on the two sides of this belt becomes markedly discordant near the north coast.

PRE-MESOZOIC ROCKS: ARDNAMURCHAN

The chief points of interest noted are:—

(1) *Moine Gneisses.*—The survey of the area of gneiss to the east of the Tertiary volcanics and plutonics, and west of the Ockle and Glenmore Rivers, has now been completed by Mr. Simpson. He finds that the gneiss is of a flaggy psammitic type with pebble-bands and subordinate mica-schist, that is nearly always garnetiferous.

North of Kentra Bay, Mr. Eyles has traced the Carna Pelitic ('Summary of Progress for 1921,' pp. 89, 90), and the psammitic belt to the east of it, through Eilean Shona to the north shore of North Channel, Loch Moidart.

Towards the western margin of the Carna pelitic belt, thin pale-coloured garnet-zoisite seams have been noted, whilst the width of the outcrop has diminished from 1½ miles at Carn Mor to about three quarters of a mile at North Channel.

East of the psammitic belt, a minor band of garnetiferous pelitic and semi-pelitic gneiss has been mapped; it is succeeded to

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 95.

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the east by another belt of psammitic gneiss. The presence in it, in the Moidart area, of numerous thin garnetiferous seams, resembling the garnet-zoisite seams of the Carna Pelitic, distinguishes this psammitic belt from that immediately to the east of the Carna Pelitic.

(2) *Lamprophyres.*—Lamprophyre dykes and sheets have been mapped in great numbers by Messrs. Eyles and MacGregor. They do not occur west of a line joining Glenmore River on Loch Sunart with Gortenfearn on the north side of the peninsula. Both foliated and non-foliated types occur, and the latter, near Loch Sunart, have been involved in obvious folding.

Camptonites.—Two additional occurrences of camptonite dykes ('Summary of Progress for 1921,' pp. 96, 104) have been noted by Mr. Simpson in Tiree, and others by Messrs. Eyles and MacGregor in Ardnamurchan. In this latter district camptonites do not occur west of a line joining Hacarsaid on the north coast and Dun Ghallain on Loch Sunart, whereas east of this line they are frequent.

The Tiree examples run W.N.W. and N.W.; and on the mainland, of 49 camptonites, 43 have directions between W. and N.N.W., and of these 26 trend between W.N.W. and W. by N.

Mr. Eyles has mapped an E.–W. dyke of unusual interest at the middle of the west of the island of Riska, Loch Moidart. It shows three continuous portions.

(*a*) The most northerly portion—4 ft. thick—consists of numerous ovoid cores of a greenish crystalline aggregate, most probably serpentinised olivine, with occasional crystals of a light brown mica like phlogopite, set in confluent sheaths of black, platy matrix.

(*b*) The middle portion consists of decayed basic igneous rocks too rotten to determine, and is about two feet across.

(*c*) The third portion is a slightly ocellar camptonite about two feet across.

The relations of the three portions are somewhat obscure, but are probably those of a composite dyke. The sheath-and-core structure is different from that occurring commonly in pitchstone, as the sheaths do not correspond in composition with the cores. Mr. Bailey last year found a sheath-and-core dyke of the Riska type east of the river mouth at Camas an Lighe, four miles farther south-west. The sheaths proved on slicing to be camptonite, and the cores decomposed olivine-nodules.

Mr. Eyles describes a small, but well exposed, volcanic vent in the south coast of Eilean Shona, Loch Moidart, about half way between Arean and Eilean Shona house. The vent, which penetrates Moine gneiss, is filled with angular, sub-angular, and rounded blocks, up to two feet in length, set in fine-grained tuff. The blocks are all of local types of gneiss and dykes with the

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exception of a number of brown calcareous nodules, pale grey on a freshly broken surface. One of these proved to be an olivine nodule very largely replaced by carbonates. A few crystals of chrome-spinel and a second ferro-magnesian mineral were observed. The original structure of the serpentinised olivine is retained.

TRIAS AND JURASSIC: ARDNAMURCHAN

In the neighbourhood of Kilchoan, Dr. G. W. Lee has confirmed Professor Judd's recognition of the Trias and of all the divisions of the Jurassic, excepting the Rhaetic, up to and including the Inferior Oolite. The basal beds of the Jurassic (Infra-lias of Judd) were specially searched for Rhaetic fossils but without result. The Great Estuarine Series is believed by Dr. Lee to be represented by certain fissile shales containing *Estheria murchisoniæ*, a fossil characteristic of this horizon in Skye. The only exposure of these beds occurs in the sea cliff at Sron Bheag, one mile S.W. of Kilchoan Bay, where it is separated from neighbouring outcrops of the Inferior Oolite by intrusions, and probably also by faults.

Mesozoic sediments have been preserved under a cap of Tertiary basalt lavas N. of Ardslignish.

On the scarp south of Lochan a' Mhadaidh Riabhach a compact limestone, which may be 25 feet thick, is seen. It is crowded with *Gryphaea arcuata* and other fossils and is of Lower Lias (Sinemurian) age. Traced eastwards along the scarp the limestone rapidly thins out. From where the limestone disappears a thin sandstone is traceable at intervals round the scarp. A good section of this sandstone seen in a small stream which enters Loch Sunart at Camas Fearna below the base of the lava is, 3 feet mudstone, 2 feet gritty conglomeratic sandstone, 3 feet conglomerate, resting on gneiss.

The conglomerate consists of well-rounded pebbles of quartz and a few angular pieces of gneiss. The matrix is grey-green and contains occasional rounded grains. The conglomerate grades up into a conglomeratic sandstone not more than five or six feet thick.

The precise geological horizon of the sandstone is uncertain; it is nowhere seen in connection with the Lias Limestone; it does not possess a markedly calcareous matrix, nor does it show the cornstone concretions often characterising the Triassic deposits of the district; and it lacks the flint pebbles and wind-rounded grains often met with in the Tertiary sandstones of Mull and Morven.

TERTIARY COAL: ARDNAMURCHAN

In the winter of 1921 a seam of coal was uncovered by a local resident, and was widely reported upon in Scottish newspapers. The outcrop of coal occurs 550 feet above sea-level, in a small stream which falls into the sea at Camas Fearna, Loch

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Sunart. The coal is from 1½ to 2 feet thick with 2 to 4 in. sandy fireclay below, resting on gneiss. It is a brown coal of poor quality, well-bedded and clean in one part of the section; but elsewhere it contains a large admixture of grit, and occasional flints. The sandy material in the coal consists of beautifully rounded quartz-grains. Above the coal are about four feet of volcanic mudstone, which contains well rounded grains of quartz in its lower portion.

A search for fossils in the confused upper portion of the coal deposit yielded to Mr. Simpson a shark's tooth, which Dr. Smith Woodward has identified as belonging to the genus *Oxyrhina*, and probably *O. mantelli*, a species of late Cretaceous or early Tertiary age. The coal is absent in stream sections on either side, so that its extent appears to be very limited.

CRETACEOUS AND TERTIARY SEDIMENTS : MORVEN

In the 'Summary of Progress for 1920' (p. 36), Mr. Bailey claimed that the Chalk of Western Mull had been exposed to desert conditions soon after its elevation. It was first weathered; then its crannies were filled with quartz-sand characterised by wind-rounded grains; finally it was silicified; and the associated sand was enclosed in a chert matrix. This took place before the advent of the warm temperate climate which witnessed the outbreak of vulcanicity in the district.

Last season, Mr. Bailey visited Loch Aline in Morven, to investigate the well-known white sandstone there exposed above the Cenomanian Greensand. He found a fair proportion of wind-rounded grains in this sandstone. In Western Mull, the similarly placed sandstone at Gribun underlies silicified Chalk, and is therefore clearly of Cretaceous date. It, too, contains apparently wind-rounded grains, but its texture is finer than that of the Loch Aline sandstone, so that a close comparison is impossible.

Under these circumstances, Dr. Lee advised a visit by Mr. Simpson and Mr. Manson to the outlier of Beinn Iadain, north-west of Loch Aline. They obtained the following succession at a point spoken of by Prof. Judd as the south-east angle of Beinn-y-Hattan :—

	Ft.	in.
Mudstone	1	6
Sandstone with streaks of lignite	2	0
Sandstone (round grains) reddish brown passing down to white; occasional plant fragments	1	9
Lignite streak	–	–
Hard white fireclay, full of roots	0	4
Lignite with rounded sand-grains	0	2
Silicified chalk with flints (Senonian)	2	6
Sandstone : glauconitic, with shell fragments in upper part, but in the main white and unfossiliferous. Most of the grains are beautifully rounded and polished, averaging 0·4 mm., but often as little as 0·2 mm. in diameter. The rounding surpasses that met with in grains of comparable size collected from the modern desert near Giza Pyramids	25	0

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	Ft.	in.
Hard calcareous sandstone, grains well-rounded; a few marine shell fragments	1	6
Soft pale-brown sandstone, some grains rounded; a few marine shell fragments	2	6
Exogyra conica Greensand (Cenomanian), quartz-grains small, but some show rounding.		

From analogy with the Beinn Iadain section the round grains of the Loch Aline Sandstone do not exclude the Upper Cretaceous date assigned to this sandstone by Prof. Judd. The millet-seed sandstone between the Senonian Chalk and Cenomanian Greensand of Beinn Iadain cannot be exactly dated, but Prof. Judd has recorded *Belemnitella mucronata* from the Chalk.

Mr. Bailey claims that the Beinn Iadain evidence shows that the desert climate, which persisted for some little time after the elevation of the Chalk, had long previously affected the continent bordering the Chalk sea; and that the sands above the Cenomanian Greensand in Morven and Mull were blown into the Chalk sea from a neighbouring desert. Mr. Hume's account of the similarly placed sands of Antrim supports this hypothesis. Moreover, in the literature of chalk residues from the Franco-British area, there are many references to rounded quartz-grains of small size. Accordingly, the suggestion is advanced that the relative absence of river-borne contamination in the European Chalk is in large measure due to a desert climate affecting the neighbouring continents.

TERTIARY IGNEOUS COMPLEX: ARDNAMURCHAN

The investigation of the plutonic complex and the surrounding rocks at the west end of Ardnamurchan has been continued by Mr. Richey. Mr. Simpson has mapped the less complicated country east of Ben Hiant.

Tertiary Lavas.—The Tertiary lavas surveyed by Mr. Simpson form a faulted outlier to the east of Ben Hiant. They cover an area of about 2½ square miles, and are separated from lavas bordering the vent complex of Ben Hiant by a N.N.W. fault which skirts the west side of the peninsula of Ardslignish, and runs up the hollow towards Loch Mudle, throwing down the lavas to the east. The southern portion of the lavas forming the promontory at Ardslignish is also a faulted block, let down some 200 feet to the south by an east-and-west fault parallel to, and on the southern edge of, the public road where it crosses the peninsula.

The group, as preserved, is about 300 feet in thickness, and where seen, the basal member is nearly always found to rest on brown volcanic mudstone usually containing some rounded sand grains. The lavas are medium or fine-grained olivine-basalts, the olivine forming small but conspicuous phenocrysts. The individual flows may occasionally be rudely columnar, and have well-marked amygdaloidal upper portions overlain by conspicuous red boles.

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Segregation veins have been noted at various localities. The lava flows dip at a low angle to the south of west. In the Kilchoan district, farther west, only small remnants of Tertiary lavas are preserved overlying the Mesozoic and pre-Mesozoic sediments.

Agglomerate Vents. Part of the well-known Ben Hiant vent was described in last year's "Summary." It forms one of a series which extends across the peninsula on the east of the plutonic complex. Only a part of this area has yet been mapped, but the agglomerates are known to be much invaded by minor intrusions including cone-sheets. Agglomerate free from cone-sheets outcrops along the east side of a promontory bounding the eastern side of Kilchoan Bay. These cone-sheets and the amygdaloidal basalt lavas cut by them are much shattered by explosions along the edge of the vent, and pass gradually into true agglomerate, which contains fragments of both, and also blocks of Mesozoic and pre-Mesozoic sediments.

Structural Features in country bordering Plutonic Complex. A general inclination away from the plutonic mass, usually at about 30°, is a feature of the sediments bordering it (Fig. 6). The simple dome structure thus indicated is complicated by faults near which variations from the general dip are found. Two curving faults, for example, have let down a strip of basalt lavas eastwards of Kilchoan Bay. The more easterly fault where seen on the shore is evidently later than the cone-sheets which there cut pre-Mesozoic grits. Perhaps the faulting is earlier than the dome, the formation of which appears connected with the intrusion of the plutonic masses. The junction between the gabbro intrusion and Lower Lias shales is well seen on the coast about 3 miles west of Kilchoan Bay. The shales dip southwards at 30° and form a roof to the intrusion, the plane of contact being parallel to the bedding. A similar relation is seen at the extreme westerly point of the peninsula, where a remnant of roof composed of shales dipping west is exposed at the top of the coastal cliff. North of Kilchoan Bay, however, the junction between the outermost gabbro and the country rocks can be followed down a steep hill-side, and is evidently highly inclined or vertical. It is possible that a doming of the roof has led to a dragging up of the walls.

Sills. In the Kilchoan district, quartz-dolerite sills are abundant in the Mesozoic and pre-Mesozoic bedded rocks. They are usually thin and are always fine-grained. In microscopic slices they are variolitic and resemble the Sgurr Dearg type of variolite from Mull. They are sometimes composite, with basic margins and acid centres, and resemble the composite sills of Skye and Mull in that the acid magma has followed the basic before complete consolidation. A good example may be seen on the shore just west of Kilchoan pier. The sills as a group are earlier than the cone-sheets, by which they are invariably cut.

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Cone-Sheets. The remnants of a circular belt of cone-sheets[1] quartz-dolerites of Talaidh type) which has been broken through by plutonic masses is shown on the sketch map (Fig. 6). A later system of sheets which cut the plutonic intrusions has been

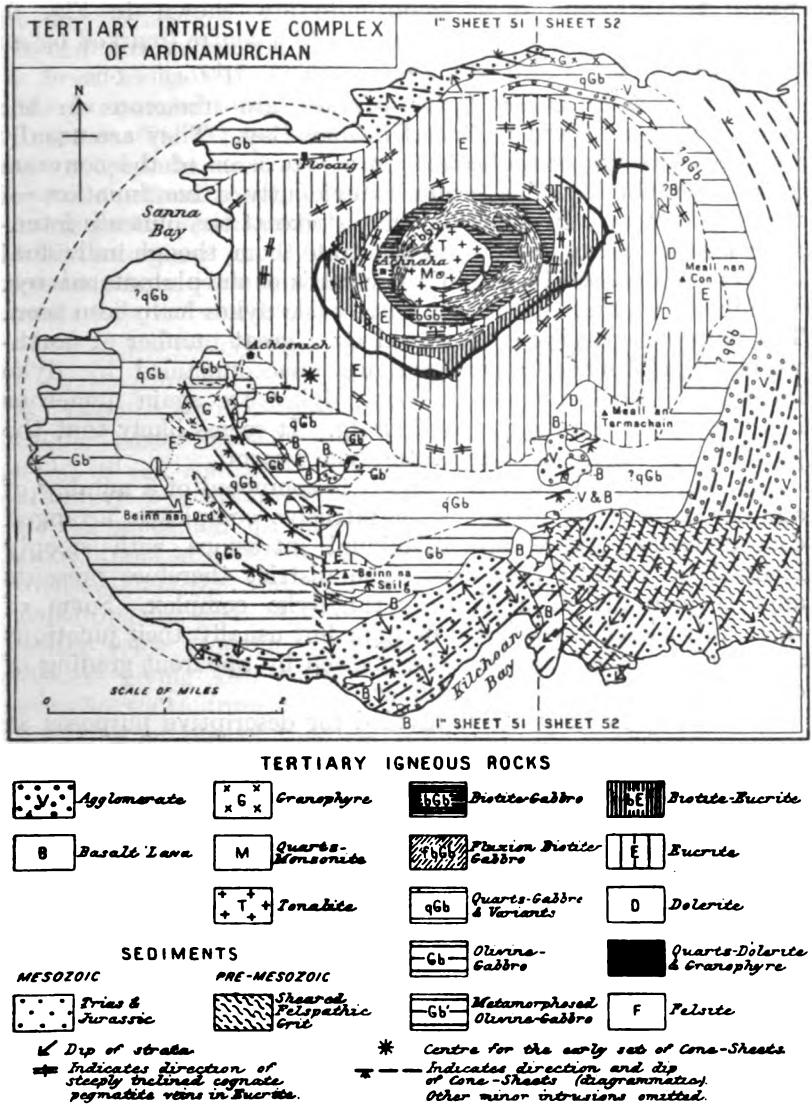

FIG. 6.—*Tertiary Intrusive Complex of Ardnamurchan.*

mapped in the south-west sector where they are fairly abundant. They differ from the Talaidh cone-sheets in being freely porphyritic and appear to be more basic. They are usually inclined at angles of 60 to 70 degrees, whereas the dip of the Talaidh cone-sheets is usually lower than 45°. The later sheets are considered

[1] 'Summary of Progress for 1920' (*Mem. Geol. Surv.*), 1921, p. 42.

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to be a partially developed system. The investigation of the relations of the two sets of cone-sheets has not been completed, but north of Kilchoan Bay, the directions of the two sets differ : the later group would appear to belong to the plutonic centre where tonalite and quartz-monzonite are shown in Fig. 6; while the Talaidh cone-sheets conform to a centre (marked by an asterisk) about 1½ miles south-west of this point.

North-westerly Basic Dykes.—Dykes are numerous in the coast section east and west of Kilchoan Bay. They are usually found to cut the cone-sheets, but a few cases of the converse have been noted. The group is evidently a continuation of the Mull swarm. In direction, they strike at the plutonic intrusions that lie inland, yet do not penetrate them, though individual dykes can be traced to within a few yards of the plutonic masses. Within the plutonic mass, only three basic dykes have been seen. The plutonic complex is traversed by a great number of north-westerly crush-lines, but these are unaccompanied by dyke intrusions. On the northern coast, dykes are again numerous in the Mesozoic strata east of Plocaig. It seems likely that the plutonic complex is later than the dyke swarm.

Plutonic Complex.—The complex is composed of a number of annular or arcuate intrusions, or intrusive complexes, arranged concentrically. There are individual intrusions with steeply inclined or vertical junctions. The district therefore presents another example of a Tertiary ring-dyke complex. Some of these intrusions have chilled margins but usually their junctions are quite unchilled, and may be masked by apparent grading of one type of rock into its neighbour.

The complex may be subdivided for descriptive purposes as follows :—

(1) Olivine-Gabbro.
(2) Quartz-Gabbro Complex.
(3) The Great Ring of Eucrite.
(4) The Central Complex.

The majority of the ring-intrusions, (3), (4) and part of (2) conform to a centre east of Achnaha, where tonalite and quartz-monzonite have been mapped. Others, (1) and part of (2), in the south-west sector, appear to have reference to the earlier intrusion-centre about which the Talaidh cone-sheets are arranged. There is considerable evidence that the ring-dykes of the Achnaha centre are a later group than the others, and that, of this group, the central members succeeded the peripheral.

Different types of scenery characterise the several belts of country occupied by the above rock-assemblages. The Great Ring of Eucrite forms high rocky ground in striking contrast to the lower-lying, grass-covered area occupied by quartz-gabbro immediately outside it. The inner side of the Eucrite-ring constitutes an amphitheatre of crags up to 400 ft. high, within which the rocks of the Central Complex form relatively low

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ground, with curving ridges and hollows that mark the course of the various intrusions composing it.

(1) *Olivine-Gabbro.* This perhaps is a single intrusion related to the early centre marked by an asterisk on the map (p. 99). In the northerly part of its southern limb, it possesses a well-marked fluxion-banding, usually inclined northwards at angles of from 35 to 65 degrees. Strips of fine-grained basic rock arranged parallel to the banding are a feature of this part of the intrusion. They are evidently xenoliths, perhaps cognate to the gabbro, and not intrusions cutting it. The gabbro becomes very fine-grained towards its outer margin. An isolated mass of olivine-gabbro north-east of Sanna Bay may perhaps be a portion of this intrusion. It also is characterised by a fine grain on its outer northern side as well as towards its inner margin against eucrite.

(2) *Quartz-Gabbro Complex.* The rock-types mapped together as quartz-gabbro show considerable variation in composition, due perhaps to absorption of more basic material; many isolated basic masses have been mapped in the south-west sector of the complex. The quartz-gabbro there has a well-developed acid mesostasis, which projects on weathered rock-surfaces as whitish patches. In the eastern sector the quartz-gabbro appears in the field to be uniformly crystalline. In the south-west sector the outermost quartz-gabbro intrusion is chilled to a fine-grained porphyritic rock along its outer boundary. Aplitic veins from it abundantly cut the olivine-gabbro in contact, giving rise to a belt of 'intrusion-breccia,' which varies in width from a few feet to a hundred yards and more. On the inner side of this quartz-gabbro, where it is in contact with a strip of eucrite, it is quite coarse-grained and has evidently extensively corroded the eucrite. The latter occurs as a vertical screen forming the backbone of the Beinn nan Ord ridge. It there separates the outer quartz-gabbro from an inner quartz-gabbro which is chilled against it (and appears to be highly baked). The screen, when traced downhill at the north end of Beinn nan Ord, disappears, and is replaced by hybrid quartz-gabbro, which forms a ridge at a lower level extending northwards towards Sanna Bay. It likewise disappears in a valley separating the south-east end of Beinn nan Ord from the west slopes of Beinn na Seilg; but is found again on higher ground opposite, and continues from there to a northern summit of the latter hill.

North-east of Beinn nan Ord, some isolated masses of highly metamorphosed olivine-gabbro, lettered Gb^1 (Fig. 6), have been mapped. This rock is characterised in the field by its dead-black colour. Under the microscope its felspars are seen to be clouded with dark inclusions. In some sections, its constituent felspar, augite and olivine, are found to have crystallised simultaneously in eutectic fashion. At contacts the rock is usually corroded by the quartz-gabbro, and the latter is

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contaminated with basic material. The masses formed of this rock-type are probably the remnants of a ring-intrusion, isolated by the later quartz-gabbro; part of its inner margin still remains in relation to agglomerate and compact basalt-lava. The outline of this inner margin indicates that the metamorphosed gabbro formed a ring-intrusion related to the early intrusion-centre about which the Talaidh cone-sheets are arranged.

A small mass of granophyre mapped to the north of Beinn nan Ord may be mentioned. It sometimes becomes more basic towards its junction with surrounding quartz-gabbro. The latter is cut by granophyre apophyses, and the granophyre is presumably a late differentiate of the quartz-gabbro magma.

A mass of agglomerate and basalt lava occurs north-north-east of Kilchoan Bay, on the south side of Meall an Tarmachain; on its west and south sides, this mass forms a roof to the quartz-gabbro intrusion, and slopes gently southwards. On its north side it is vertically cut across by the margin of the Great Ring of Eucrite.

On the north side of the peninsula a good many Talaidh cone-sheets cut the quartz-gabbro, and are very abundant in the Mesozoic strata hard by. They fail to penetrate the eucrite mass whose outer margin obliquely crosses their direction. There is thus some evidence of the quartz-gabbro having preceded the intrusion of the eucrite ring.

(3) *The Great Ring of Eucrite.*—This rock is always coarsely crystalline, and olivine is usually a conspicuous mineral. The relative amount of olivine and augite varies very considerably, and frequently one mineral is developed to the practical exclusion of the other. The felspar is either bytownite or anorthite. In the eastern sector an outer mass of eucrite grades into highly baked dolerite against which, along a vertical junction, an inner eucrite is appreciably chilled. The dolerite occurs on the adjoining hills of Meall nan Con and Meall an Tarmachain, but it is absent in the valley between.

A feature of the eucrite mass as a whole is a development of thin cognate pegmatite veins. They often follow a straight course (in the eucrite) extending for many yards, and are vertical or steeply inclined. At any particular locality these regular veins are very closely parallel; they change direction from place to place, so as to run everywhere parallel to the margins of the ring-intrusion. They are sometimes multiple with borders rich in augite, and felspathic centres, or vice-versa.

The normal eucrite frequently contains patches of very coarsely crystallised gabbro or eucrite, which are sometimes in continuity with the pegmatite veins. The veins are considered to have been formed late in the consolidation of the eucrite mass, and to represent contraction cracks into which residual magma found its way. The parallelism in direction between the regular system of veins and the margins of

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the ring-intrusion is so striking that it seems reasonable to accept the vertical or steep inclination of the veins as evidence of the essentially dyke-like form of the whole intrusion.

(4) *The Central Complex.*—This is composed of a number of ring-intrusions. Its various rock-types, except the quartz-dolerite ring dyke, are characterised by containing biotite. The amount of biotite varies according to the acidity of the rock. It is very rarely seen in normal eucrite, and in biotite-eucrite it is rather scarce. In biotite-gabbro the mineral is plentiful, while in tonalite and quartz-monzonite it is abundant.

Quartz-Dolerite and Granophyre Ring-dyke.—This narrow dyke, about 30 yds. wide, outcrops at the foot of the amphitheatre of eucrite crags already described. It has been intruded approximately along the inner margin of the Great Ring of Eucrite, but deviates a little on either side of this line. It consists of quartz-dolerite reticulately veined by granophyre or felsite. Outcrops are abundant but marginal exposures are few. At the east side of the Central Complex, however, the quartz-dolerite is seen chilled against eucrite on its outer margin, and the junction is inclined eastwards, *i.e.*, outwards, at about 70 degrees. A little north of this, close to its northern termination, the dyke is only 3 ft. wide, and is replaced a few yards farther north by a gabbro or eucrite breccia strung with granophyre veins. This narrow dyke of intrusion-breccia has clean-cut junctions with solid eucrite on either side; and its walls are inclined north-eastwards, *i.e.*, outwards at 70 degrees.

Biotite-Eucrite.—The rock is typically a felspathic eucrite containing scattered flakes of biotite. It weathers comparatively easily and may thus be distinguished in field exposures from eucrite proper, with which it is in contact. A sharp junction has been noted between the two types of eucrite where the boundary line between biotite-eucrite and the inner narrow eucrite ring-intrusion crosses a track leading from Achnaha and Plocaig.

The Inner Ring of Eucrite.—This eucrite generally gives rise to a low ridge. It everywhere carries cognate pegmatite-veins, with conformable strike and steep inclination.

Fluxion Biotite-Gabbro of Sithean Mor.—The rock-type is a medium-grained, dark gabbro, with well-formed felspars arranged parallel to one another. Biotite is usually fairly plentiful. An intrusion of this rock-type forms the curving steep-sided ridge of Sithean Mor at the south side of the Central Complex. In the south half of the ridge, the fluxion gabbro is interbanded with a more felspathic coarse-grained gabbro. The bands are vertical or steeply inclined. They conform in direction to the changing course of the northern

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steep slope of the ridge, which agrees closely with the inner margin of the intrusion. On the south side of the ridge coarse biotite-gabbro and eucrite, which is mapped as part of the Great Ring, are cut by a dyke-like irregular intrusion of basic rock containing biotite. The intrusion has chilled edges and appears to be an offshoot from the fluxion biotite-gabbro; its occurrence at any rate indicates that the biotite-bearing rock series of the Central Complex is of later origin than the biotite-free eucrite of the Great Ring.

The Glendrian Ring-dyke of Fluxion Biotite-Gabbro.—The course of this intrusion is marked by a conspicuous ridge encircling an area occupied chiefly by tonalite. The intrusion forms a complete ring, except for an interruption near Achnaha, where it is broken through by the later intrusion of tonalite. The rock is often fissile, owing to its very perfect fluxion-structure, which was frequently noted to be parallel to the direction of the ring-dyke, and to be steeply inclined. The margins of the intrusion are unchilled. A sharp junction with biotite-gabbro outside it is well-exposed along its south side.

Biotite-Gabbro.—This type is very coarsely crystallised, with biotite plentiful. Quartz is often seen in hand specimens while olivine is absent or scarce. Large irregular crystals of iron-ore are usually plentiful. The detached areas formed of biotite-gabbro as shown on the map, appear to be portions of one ring-intrusion separated by the latter Glendrian Ring-dyke of fluxion biotite-gabbro. An unchilled contact between the latter and one of the outer portions has been already mentioned. No actual contacts with the Inner Ring of Eucrite, which encloses it, have been observed. Their distinctness seems to be clearly established west of Achnaha, where the Inner Ring of Eucrite forms a little ridge, along the eastern side of which it becomes finer grained, next to outcrops of very coarse biotite-gabbro.

Tonalite.—This mass is fairly uniform in composition, and becomes progressively finer-grained towards its outer margin; numerous acid apophyses occur in the surrounding gabbros. An elongate strip of gabbro, probably a " screen," occurs in the south-east part of the mass : on its outer side tonalite is chilled in contact with it.

Quartz-Monzonite.—A small eminence rises in the centre of the peat-covered ground occupied by the intrusion just described. Its summit is composed of a small mass of quartz-monzonite which presents a sharp, slightly-chilled, margin against the tonalite surrounding it. Its outcrop, as will be seen on the map, is elongated in the same north-easterly direction as the tonalite and gabbro rings by which it is surrounded.

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Glaciation: Tiree and Ardnamurchan

Tiree. On Ben Hynish, at the south-west end of Tiree, Mr. Simpson has observed numerous striae pointing N. 20° W. and N. 30–35° W. The ice-movement was probably from south-east since in Iona and Coll the striae are directed N.W.

Kentra Glacial Fan: Ardnamurchan. East of Kentra Bay, a large peat moss extends 2 miles from north to south and 1½ miles from east to west. Sand and gravel underlie the thick peat, and are well stratified in a section 650 yds. W. of Shiel Bridge, where 11 ft. of sand and gravel may be seen under 4 ft. of peat.

South of the River Shiel the eastern limit of the gravel lies between Acharacle School and New Shiel Bridge, and forms a very irregular eastward-facing scarp, 10 to 15 feet high. Two or three small discontinuous eskers lie just east of this scarp, one of them being confluent with the gravel spread. The hollow which contains the eskers falls gently eastwards to merge with a broad alluvial flat bordering Loch Shiel. These Kentra gravels apparently represent a large glacial outwash-fan; while the scarp marks the former margin of a glacier occupying Loch Shiel; and the gravel-eskers, the courses of subglacial streams. Near the eskers, a small kettle hole occurs in low-lying gravel. The question arises whether this spread of gravel was laid down in a shallow sea and sorted by the waves, or was deposited on a land surface by glacial streams. The ground has a gentle slope and the Kentra gravels thin out from east to west, until a faintly marked raised-beach bluff is encountered a few feet above high-water mark. In the scarp the gravel reaches a height of 60 feet above O.D., while at Kentra, rather more than a mile away, its surface is only 16 feet above O.D. On this evidence it seems clear that the gravel accumulated on dry land. Mr. Bailey, who has seen both localities, states that the Kentra fan and eskers reproduce on a larger scale the phenomena occurring at the mouth of Glen Forsa, Mull.[1]

Economics: Tiree and Morven

Two items of economic interest were investigated in the course of last season's field work.

(1) *Magnetite, Tiree.* Mr. Simpson has mapped a deposit of magnetite at the north-west corner of Loch a' Phuill, immediately east of a stone fence which runs N.N.E., parallel to, and about 80 yards away from, the shore of the loch. The magnetite is in the form of a band striking N.N.E. in conformity with the bordering gneiss, and is visible for about 150 yards before it disappears under surface deposits.

The band is about 13 feet in breadth, and the middle seven feet appear to be fairly pure, but towards the edges

[1] 'Summary of Progress for 1909' (*Mem. Geol. Surv.*), 1910, p. 37.

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the magnetite is interfoliated with quartz and garnet to a notable extent.

A sample from the middle portion has been analysed by Mr. Sutcliffe and has been found to contain only 27·93 per cent. iron.

(2) *Glass-sand.* A friable white sandstone, 20 feet thick, adjoins the road neighbouring Loch Aline for about a mile and a quarter north-east from the village. It generally outcrops towards the foot of a steep escarpment. Its immediate roof is furnished by a few feet of mudstone, but above this comes basalt lavas which would allow of easy mining of the sandstone. The loch affords opportunities for shipping at any tide and almost any weather. Mr. Bailey has had a specimen analysed, with the following result :—SiO_2 99·69; Fe_2O_3 0·02 per cent.

4. North Highland District

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G. V. Wilson, B.Sc., Senior Geologist.
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D. Haldane, B.Sc.
G. Ross, B.Sc.
J. Phemister, M.A., B.Sc.
} Geologists.

Field work was carried on during the summer in one-inch Sheets 102, 108 and 103. The unsurveyed area between Lubcroy and Corriemulzie in the south-west of Sheet 102 was mapped and a re-examination made of part of the igneous complex of Sgonnan Beag. This Sheet is now completed. A considerable area in the south-central and central parts of Sheet 108 was surveyed, and in addition a rapid revision made of nearly half of Sheet 103, with the object of preparing a new colour-printed edition of this map showing the " drift " geology in addition to the " solid."

Sutherlandshire

One-inch Sheet 102 (Lairg Sheet)

In the Corriemulzie district to the south-west of Oykell Bridge (Sheet 102), Messrs. Haldane and Ross report the occurrence of a broad area of garnetiferous mica-schist extending northwards for about four and a half miles from the south margin of the Sheet and forming a continuation of the pelitic belt mapped in the north-west of Sheet 93.[1]

The rock is a medium-grained corrugated muscovite-biotite-schist, generally with abundant garnets. On the western margin the prevailing dip is to the east or south-east at moderate angles, but there is considerable local variation and contortion. The junction of these pelitic rocks with the siliceous granulites

[1] 'The Geology of Ben Wyvis,' etc., Explanation of Sheet 93 (*Mem. Geol. Surv.*), 1912, p. 31.

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to the west is generally marked by extreme interfolding, but their northern edge is sharp, and defined, at least locally, by a fault line. The north-eastern margin between Creag Loisgte and Cnoc nam Bad Bog is much-folded with prevalent south-west dip. The remainder of the area northwards to Luberoy is occupied by siliceous or banded siliceous and semi-pelitic granulites, often rodded and containing narrow belts of garnetiferous mica-schist.

The area between the Sgonnan Beag and the Moine thrusts has been revised by Mr. Phemister. He finds that, though the structure is complicated by an abundance of minor thrusts, the igneous intrusion in this area appears to be of a laccolithic nature and in all likelihood forms part of the Cnoc na Sroine magma. Its base probably rests on the Pipe Rock and its roof is formed, sometimes at least, by the Durness Limestone. Inclusions of the Limestone, Serpulite Grit, Fucoid Beds, and Quartzite are found within the igneous rock, at one locality in their proper stratigraphical sequence.

The igneous rocks can be divided into two main portions, an upper alkaline part (syenite), occupying by far the larger superficial area, and a lower ultra-basic part of variable composition. The syenite is mostly soda-felspar with varying accessory minerals, including garnet and riebeckite. Borolanite in the restricted application of the term suggested by Dr. Shand[1] has not been met, but a felspar-melanite rock which would be included under the term "borolanite" as used by Drs. Horne and Teall,[2] has been collected from several localities where it is associated with limestone, in one case very intimately.

At many places basic "knots" are found in the syenite, the most instructive locality being the Oykell River just below its junction with the Allt Sail Ruathair, where the following downward succession is found, (*a*) syenite, (*b*) syenite with basic knots, (*c*) basic rock with syenite veins, (*d*) basic rock with fewer veins of syenite and enclosing ultrabasic patches. A further downward succession may be seen in exposures on a small hill in the north-eastern corner of the area at the headwaters of the Amhainn Gleann na Muic, where basic rock veined by syenite rests on an ultrabasic mass with diorite veins.

One-inch Sheet 108. (*Altnaharra Sheet*)

Mr. Wilson mapped the ground around the Fiag River between Loch Shin and Ben Hee. He reports that this area is almost entirely occupied by normal siliceous granulites with a general dip to the N.E. at about 45°. In one of the small streams which flow into the Fiag River from the east a thin band of calcareous rock was noticed, and on microscopic examination found to contain brucite.

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[1] S. J. Shand, 'On Borolanite and its Associates in Assynt,' *Trans. Edin. Geol. Soc.*, vol. ix, 1910, p. 415.

[2] J. Horne and J. J. H. Teall, 'On Borolanite,' *Trans. Royal Soc. Edin.*, vol. xxxvii, 1895, pp. 163–178.

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The area surveyed by Messrs. Ross and Phemister to the west of the Lairg-Altnaharra road includes the ground round Loch Ben Harrald and An Glas-loch and extends westwards for several miles. The prevailing rock is a rather coarse quartzo-felspathic granulite, grey or pinkish in colour and generally massive. The prevalent dip is east at angles of 25 to 40 degrees, and in this direction the rocks become more flaggy and micaceous layers more numerous. This banded type continues eastwards nearly to the Allt a' Ghlas-locha. Here Mr. Phemister finds that they pass beneath a series of granulites containing hornblende. These hornblendic rocks are undoubtedly an integral part of the schist series. In composition they vary from a black hornblende rock to a grey granulite speckled with radial aggregates of hornblende up to an inch in diameter. The conspicuous, often minute, banding due to alternate hornblendic and felspathic layers is very persistent, and some specimens recall the striped schists described by Mr. Read from the Allt Doire a' Chatha in Sheet 102[1]; other hand specimens resemble the hornblende-schists associated with the Shiness Limestone. Where seen in the Allt a' Ghlas-locha these hornblende-granulites have a persistent strike in a direction slightly E. of N., and appears to be sharply folded about an axis directed generally 5 to 15 degrees E. of S. and pitching to the S. The series of banded siliceous and biotite schists which underlies them to the west reappears east of the Allt a' Ghlas-locha with a dominant westerly dip. This suggests that the hornblende rocks occupy the core of a southward pitching synclinal fold. Somewhat similar types were found by Mr. Ross among the flaggy schists just north of the summit of Meall an Fhuarain where occasional thin layers are formed almost entirely of acicular hornblende.

The striped schists described above are immediately underlain in the Allt a' Ghlas-locha by quartz-felspar-granulites, and these overlie a broad belt of massive biotite-hornblende rocks or amphibolites. Two outcrops of similar rock were noted in a burn 650 yards E. 20°S. of the northern exit of An Ghlas-loch; one of these, 6½ feet thick, contains inclusions of different types of the granulites. Pyrites is abundantly scattered through it. The schists immediately below show much chlorite in papery laminæ. A sill-like intrusion of a coarse-grained faintly gneissose hornblende-felspar-rock, about 2 feet wide, was noted by Mr. Ross on the south-west slopes of Meall an Fhuarain. It occurs in a semi-pelitic band and is margined by a well-foliated gneiss with augen of pink felspar and streaks of granular quartz in a biotitic matrix.

A large proportion of the area surveyed in this Sheet is covered by morainic drift or peat. Mr. Wilson notes that on the south-west of Loch Shin, opposite the mouth of the Fiag River, the glacial striae show an east-and-west orientation indicating that

[1] 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, pp. 101–102.

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the pressure of ice from the Ben More massif to the west was apparently sufficient to cause a deviation of the Loch Shin ice from its south-easterly course. Mr. Ross finds the average direction of striae on Creag Dubh Mhor and on the high ground west of the intake of An Ghlas-loch directed N. 31°E. thus betraying a general north-easterly movement during the period of maximum glaciation. Striae near the 1,100-ft. level indicate a somewhat later stage when the ice moved in a more easterly direction down the Allt an t-Sratha Dhuibh into the Mudale valley. Crescentic moraines are common along the course of the former, and a terminal moraine occurs a few hundred yards upstream from the junction with the Allt a' Ghlas-locha. The pass of Bealach na Creage Duibhe and the upper part of the valley of the Allt a' Ghlas-locha represent overflow channels draining north-eastwards from the low ground to the south.

One-inch Sheet 103. (*Golspie and Brora Sheet*)

The area revised by Mr. Read lies along the Fleet valley from the west margin of the Sheet to Aberscross, extending northwards nearly to the headwaters of the Brora and southwards to an east-and-west line through Loch Laoigh. The southern part of the Sheet from Dornoch westwards fell to Mr. Haldane while Mr. Macgregor remapped the high ground to the west and north-west of Golspie.

The noteworthy features of the ground revised by Mr. Read are a splendidly exposed complex of granite and granulite, and a varied hybrid series between scyelite and granite.

Granulites and Hornblende-schists. The groundwork of the country is formed by Moine granulites which only occasionally depart from the normal siliceous character of the East Sutherlandshire granulites. The variations from this type are due to an increase in mica-content or, rarely, to the presence of much epidote, but these variations are quite subordinate. The granulites are well seen in the Aberscross district and on both sides of Strath Càrnaig.

On Creag Dail na Meine in Strath Càrnaig, and elsewhere, there are pod-like bands of hornblende-schist in the siliceous granulites. The rock is a striped association of hornblende and felspar and is foliated in accord with the regional foliation of the surrounding granulites, but it has been noted that occasionally the elongation of the pods is markedly divergent to the bedding of the granulites. This suggests that these lenses represent basic dykes intruded before the foliation, by which the new-formed hornblende and felspar have been orientated in accord with the dominant stresses. A dyke of hornblende-schist, sometimes garnetiferous, has been noted by Mr. Haldane at Creag Asdale, 2½ miles N.W. of Clashmore; this dyke has contact-metamorphosed the granulites adjacent to it.

Granite and Granite-granulite Complex. The granite concerned in this complex is the eastern continuation of the Lairg granite

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of Sheet 102. The interior type of granite is an extremely coarse hornblende-biotite-granite often with porphyritic crystals up to 4 cms. in length. Two varieties can be distinguished, a hornblende-biotite-granite and a biotite-granite but, as yet, no characteristic distribution of the two types has been found. The granite holds abundant basic patches which are sometimes modified granulite, at other times probably altered scyelite (p. 111). The rock is well seen on both sides of Strath Fleet about Pitfure, Dalmore and Tressady. It was worked about 40 years ago by an Aberdeen firm at Rogart granite quarries, Dalmore, but, though it was of excellent quality for structural work, the black patches militated against its use for monumental work, for which it was mainly required.

The margin of the interior granite runs roughly north and south from Dalmore by Leathad to East Langwell. East of this line and west of the granulites of the Aberscross district there is a complex of granite and granulite. Several zones of the complex may be distinguished, though certain of them may be lacking at different localities. They are in order from west to east :—(1) interior granite, hornblende-biotite-granite and biotite-granite, with dark inclusions; (2) a fine-grained hornblende-granite; (3) a biotite-granite occurring in layered fashion as if replacing banded granulites; a few granulite relics occur, some rich in visible sillimanite; (4) an injection-zone of biotite-granite *lit-par-lit* with granulite; many aplite and pegmatite veins occur in this zone; (5) an inclusion zone in which there is almost as much granulite as biotite-granite; (6) a zone of apophyses, mainly granulite with innumerable aplite and pegmatite veins; (7) granulites with occasional pegmatite or aplite veins.

These zones may be studied on traverses from the interior granite eastwards along the road from Pitfure to the Mound. The layered granite of zone 3 is the only belt in which assimilation may have occurred; in this zone there are no definite boundaries between the granite and the relics of granulite, and these latter are thoroughly permeated by granite.

Scyelite and Scyelite-granite hybrids. In the 'Summary of Progress for 1920,'[1] rocks hybrid between scyelite and granite were described from Ach'uaine in Sheet 102. More numerous and far finer examples of these hybrids have been found by Mr. Read in Strath Fleet. In all, some thirty small hybrid masses have been mapped, the largest reaching only about $\frac{1}{8}$ square mile in area. The larger masses are situated near Loch Beag na h-Airidhe and are shown on the published map as epidiorite. Most of the scyelite masses are situated within the granite or the granite and granulite complex, but some, composed mainly of scyelite, are found in the granulites of Strath Càrnaig. As usual, these hybrid masses form conspicuous green knobs. The ultrabasic scyelitic member is a coarse olive-green rock, quite unfoliated, and composed of olivine, hornblende and biotite;

[1] *Mem. Geol. Surv.*, 1921, p. 46.

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by mixture with granite innumerable varieties are formed, consisting of hornblende, pyroxene, biotite, felspars and quartz; these have not yet been subjected to microscopic examination.

In the hybrid mass north of Loch Mòr na h-Airidhe the scyelite is in places veined by aplite which includes angular xenoliths of scyelite. These xenoliths are marginally altered to hornblende, thus suggesting that the non-sedimentary hornblende inclusions in the Rogart granite may represent modified scyelitic xenoliths.

Mr. Haldane has noted a small boss of hybrid rock half a mile N.N.E. of Loch Lannsaidh.

Old Red Sandstone. On the south side of Strath Fleet the high ridge running from north of Torroboll by An Droighneach to Loch Mòr na h-Airidhe is formed by a narrow belt of Old Red Sandstone conglomerate which lies unconformably on the granulites and granite at its north margin, but which is limited on its south side by a fault probably a continuation, as shown on the published one-inch map, of the Loch a' Vicair fault north of The Mound Station. Near Loch Mòr na h-Airidhe the Old Red Sandstone rocks fill up irregular hollows in the old floor.

The ground examined by Mr. Macgregor to the west and north-west of Golspie consists mainly of Old Red conglomerates and sandstones. Attention may be drawn to the prominent escarpment of conglomerate which runs north-westwards from the Silver Rock to Cnoc na Gaimhne and then turns north-eastwards to Loch Brora. Along this line the conglomerate rests on an eroded surface of crystalline schists. The junction for the most part is obscured by drift or peat, but in several of the small streams which descend to Strath Lundie the conglomerate is seen resting almost directly upon the schists. Perhaps the best section, however, is that exposed in the burn flowing N.N.W. from Ben Horn to join the Scottarie Burn near the 718-ft. point; in this burn, about 700 yards from its mouth, the conglomerates rest upon the denuded edges of the weathered and stained schists. The prevalent dip of the conglomerates varies from S.S.E. to S.E., while the foliation of the metamorphic rocks, for the most part following the original bedding planes, has an E.N.E. to N.E. dip often at high angles. The schists are normal siliceous or banded siliceous and semi-pelitic granulites with a good many reddish acid granite and pegmatite veins. The boulders in the overlying conglomerates appear to be entirely local in origin; all the types of rock noted among them occur abundantly in the schist or granite-schist areas immediately to the west. The conglomerate is generally rudely bedded, and the boulders are for the most part highly angular; in the coarser bands these may attain a diameter of 2 feet. A very marked crush-line, not noted on the existing maps, traverses the conglomerate exposed in the upper part of the Allt Coire Beinn Lundie. These conglomerates pass upwards through gritty and pebbly beds into dark-brown flaggy sandstones well seen in the small quarries at the side of the Dunrobin Glen road at Backies.

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One of the most interesting features of the Beinn Lundie area, not brought out on the published one-inch Sheet, is the extent to which the high ground is buried under peat. Rock exposures are confined to a few crags or to the sides of the glacial overflow channels mentioned below. Nearly the whole of Cnoc na Gaimhne again is under peat. The thickest peat noted was 12 feet at a height of just over 1,000 feet in Coire Cnoc na Gaimhne.

The upper portions of the Allt Creag a'Ghlinne and Allt Coire na Moine, and the hollow east-and-west feature in which Loch nan Caorach lies, are well-developed glacial overflow channels now almost dry. The direction of ice-movement in this area is clearly indicated by the boulders of grey Rogart granite (Dalmore type) scattered over Beinn Lundie. A few boulders referable to the scyelitic mixtures noted above (p. 110) by Mr. Read also occur.

Mr. Haldane reports that the western half of the area examined by him in the south part of one-inch Sheet 103 is occupied by crystalline schists, the eastern half by sediments of Old Red Sandstone age. The schists are the normal flaggy and colour-banded granulites which cover so much of eastern and central Sutherland; mica-schist bands occur fairly frequently, one of which, over a hundred yards wide, is well-exposed half-a-mile south of Loch Lannsaidh. In the area of Old Red Sandstone rock exposures are few. A small outcrop of conglomerate, resting unconformably on a weathered surface of schist, is seen in a gully 500 yards W.S.W. of Overskibo near the south margin of the Sheet. No further section of the junction is exposed until, four and a half miles to the north-east, a small stream on the south face of Ben Tarvie shows the broken and weathered schist overlain by conglomerate.

A prominent feature in the area is the long kame-like ridge of sand and gravel which extends for over two miles in a W.S.W. direction about a mile west of Dornoch. It rises abruptly to a height of 50 or 60 feet and embayed in its central part is the deep marshy hollow of Lochan Treathail. The materials comprising it are very uniform in character, consisting of sand and gravel with small well-rounded stones. Numerous isolated gravel mounds occur along the northern side of the River Evelix. It seems probable that this stream originally flowed eastwards to the sea near Dornoch, instead of turning sharply south-westwards at Evelix Bridge to enter the Dornoch Firth south of Skibo.

III.—PETROGRAPHICAL WORK

1. England and Wales

Petrographical work connected with England and Wales has chiefly been carried out by Dr. Thomas as the result of enquiries from private individuals and Government Departments.

Further investigation was undertaken for the Government Laboratory into the optical properties of certain artificial

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compounds connected with the manufacture of explosives. A series of specimens submitted by Mr. B. H. Cunnington of Devizes from a prehistoric site at Cannings Cross was of considerable interest. An examination by Dr. Thomas and Mr. Hallimond showed that iron-smelting had been carried out and that the slags, which consisted of magnetite, fayalite and silica, indicated the employment of a method of smelting similar to that usually known as the acid-hearth process. The process probably consisted of the reduction of a rich ore by charcoal on a siliceous hearth.

Dr. Thomas prepared for the memoir on the Nuneaton district an account of the pre-Cambrian and post-Cambrian igneous rocks of that region. The post-Cambrian intrusions that are more particularly associated with the Stockingford Shales are of petrographical interest on account of the extreme variation of type met with in one and the same rock-mass. It would appear that the admixture and gradation of types seen in many of the larger quarries are too rapid and pronounced to be explained by the simple differentiation of acid from basic material in place, but that the explanation is to be sought in composite intrusion. Many of the rocks are clearly referable to the proterobases, and variations towards picrites on the one hand and camptonites on the other are met with.

2.—Scotland.

Dr. Thomas and Mr. Bailey have been largely concerned with the petrography of the Island of Mull. In the petrological introduction to the forthcoming Memoir on Sheet 44, in which they have utilized to the full the many chemical analyses made by Mr. E. G. Radley, they have discussed the character of the magma-types that have given rise to the Tertiary igneous rocks of Mull.

It has been found convenient to assign a large proportion of the rocks to four great subdivisions of a magma-series. These subdivisions may be specified as follows :—

	Silica Percentage.
(1) Plateau Magma-Type	43—47
(2) Non-Porphyritic Central Magma-Type	47—55
(3) Intermediate and Sub-Acid Magma-Types	55—70
(4) Acid Magma-Type	70—74

For the purposes of the present brief statement, the scope of these various magma-types is best outlined by the mention of well-known rock-types that represent them.

(1) *The Plateau Magma-Type* is represented by the bulk of the Plateau Basalt Lavas and Early Basic Cone-sheets, as well as by many of the dykes of the island. Its crystallization, in known occurrences, is commonly basaltic or doleritic, and is characterized, among other things, by an abundance of olivine

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and purple-tinted augite. Where olivine retains its freshness residual analcite is quite commonly encountered.

2. *The Non-Porphyritic Central Magma-Type* is represented by such well-known basalt-lavas as that of Staffa which accompany the Plateau Basalt-Types. It recurs in force among the Later, or Central, Basalt Lavas; and where these have pillow-structure the crystallization tends to become variolitic in character. Among minor intrusions it is abundantly represented by variolite, tholeiite and quartz-dolerite; and, among the ring-dykes it figures prominently as quartz-dolerite and quartz-gabbro.

3. *The Intermediate and Sub-acid Magma-Types* are represented among minor intrusions by andesite (leidleite and inninmorite) and by a more crystalline rock-type designated craignurite. It may be mentioned that the andesites are often vitreous and partake of the nature of pitchstones. Among the major intrusions, the rock-type developed is an aberrant augite-diorite.

4. *The Acid Magma-Type* is represented by rhyolitic tuffs, etc., and by felsitic and granophyric intrusions.

The main order of manifestation of this magma-series seems to have been from basic to acid; at any rate, much of the igneous history of Mull can be accounted for by the assumption that there have been two major magmatic cycles, each leading from basic to acid, the last cycle being followed by a recrudescence of basic magma. In general terms the succession of magma-types may be elaborated as below :—

CYCLE I.

First Stage.—Eruption of Plateau Group of Lavas mostly referable to the Plateau Magma-Type.

Second Stage.—Eruption of Central Group of Lavas of Central Magma-Types, in large measure non-porphyritic.

Third Stage.—Intrusion-period of early granophyres giving rise to the first major intrusions of Mull. Paroxysmal explosions, and the intrusion of certain Early Felsites, etc.

CYCLE II.

First Stage.—Intrusion of Early Basic Cone-sheets, mostly of Plateau Magma-Type.

Second Stage.—Intermittent intrusion of Late Basic Cone-sheets of predominantly Non-Porphyritic Central Type.

The intrusion of these Cone-sheets is interrupted in point of time by the intrusion of extensive ring-dykes that range from Non-Porphyritic Central to Acid Magma-Type; among these ring-dykes acid types predominate towards the close of the period of their intrusion.

FINAL RECRUDESCENCE.

Some north-west dykes constitute the latest igneous rocks of Mull and include typical representatives of Plateau Magma-Type.

A feature of the Non-Porphyritic Central, and of the more crystallized representatives of the Intermediate Magma-Types is the free migration of their acid residuum, and the extent to

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which this residuum has exerted chemical action on the early-formed crystals. In several of the ring-dykes gravitation has resulted in the separation of the mobile acid residuum at the top of the intrusion, where it has consolidated as granophyre : a thousand feet lower in the intrusion there may be found quartz-gabbro with pseudomorphs after olivine, and in the interval every gradation between the extremes in uniform succession.

The exposed differentiation-columns of Mull reproduce all Magma-Types from (2) to (4) inclusive (*see* above). It is difficult, however to gauge the degree of genetic relationship of Magma-Types (1) and (2) to each other. The suggestion is made tentatively in the Memoir that Type (1) may have given rise to Type (2) as a consequence of deep-seated assimilation of siliceous country-rock.

The Magma-series outlined above does not include all the igneous rocks of Mull. There are

(1) *Alkaline Products*, such as mugearite, alkaline trachyte, alkaline syenite and bostonite; these though of small bulk are interesting as indicating divergences from the main path of magmatic differentiation.

(2) *Eucrite and Allivalite*, constituting the Ben Buie Complex.

(3) Rocks of Porphyritic Central Magma-Type.

The Ben Buie Complex, predominantly of eucrite, dates from near the close of the early Basic Cone-sheets (first stage, Cycle II).

The Porphyritic Central Magma-Type tends to associate itself in the Mull record with the Non-Porphyritic Central Type. It is largely represented among the lavas (second stage, Cycle I), and later on by such of the Early Basic Cone-sheets as are of later date than the Ben Buie Eucrite (close of first stage, Cycle II). In its variolitic, basaltic and doleritic crystallizations, it is marked by its abundant porphyritic basic felspars—a feature that fails only when a gabbroid texture is assumed.

The established silica-range of the type is from about 45 to 50 per cent. Compared with the Non-Porphyritic Central Magma-Type, the chemical features of importance are the relatively high percentage of Al_2O_3, and also, except in the acid representatives, of CaO. Other differences are relatively low percentages of K_2O, TiO_2, and total iron. A Porphyritic Central Lava from Mull with 47 per cent. SiO_2, has 21 per cent., Al_2O_3, and 13 per cent. CaO. A part of the Cuillin Gabbro of Skye, referable to the same Magma-Type, has 46 per cent. SiO_2, 26 per cent. Al_2O_3, and 15 cent. CaO.

If the Non-Porphyritic Central Magma-Type has originated through contamination of an original magma by siliceous country-rock, it is at least as probable that the Porphyritic Central Magma-Type owes its character to the assimilation of aluminous material.

Only one other matter of interest need be touched upon in this brief summary, namely, the results of pneumatolysis, or propylitization, to which Prof. Judd first directed attention.

Within a roughly circular area, ten miles in diameter, including most of the intrusions of the island, it is impossible to find a

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basalt-lava that contains olivine in a fresh condition; although, outside this limit undecomposed olivine is everywhere to be met with. The destruction of analcite, and to a less extent of basic felspar are changes that accompany the decomposition of olivine. The characteristic minerals of the pneumatolysed area are albite, epidote and chlorite.

Pneumatolysis has affected most of the intrusions of Central Mull in addition to the lavas, though frequently not to such a great extent. Thus the latest basalt-dykes of Mull have had their olivine decomposed where they traverse the Central region, but the area within which this change takes place is less extensive than in the case of the adjacent lavas.

It must be remembered that such Mull lavas as have escaped erosion are amongst the earliest igneous products of the district which are available for study, so that their relatively excessive pneumatolysation in the Central region might be explained as the result of cumulative attack. On the other hand, some early intrusions have suffered less than others of later date within the same region, and in such cases it would appear that the massive character of the rock, such as the Ben Buie Eucrite, acted protectively against pneumatolysis just as, to-day, it does against weathering.

Mr. Read has incorporated in the text of the Memoir on Sheet 54 (Moor of Rannoch), and supplemented where necessary, the descriptions of rocks from that Sheet furnished by Dr. Thomas.

Messrs. Read and Phemister have commenced petrographical work connected with Sheet 102 (Lairg), and the results of Mr. Phemister's preliminary examination of the alkaline igneous rocks of Sgonnan Beag are summarized on p. 107.

A re-examination of the trachytoid phonolite of Traprain Law, East Lothian, was undertaken by Mr. A. G. MacGregor. This examination, partly of an official character, resulted in the verification of the presence of nepheline and analcite and the recording for the first time of olivine and sodalite. After the petrographical work was completed a new complete analysis was made by Mr. Ennos in the Survey Laboratory. Mr. Ennos found that the percentage of chlorine would indicate the presence of at least 2·71 per cent. of sodalite. Full details and references to literature will be found in a paper by Mr. MacGregor and Mr. Ennos which has appeared in the Geological Magazine.[1]

IV.—CHEMICAL WORK

The analytical work for the past year was of an especially varied character. To complete the Report on British Refractory Materials six fireclays were analysed and, for a memoir on Sedimentary Iron Ores, an examination was made of eleven ores with a

[1] 'The Traprain Law Phonolite,' part i, by A. G. MacGregor, M.C., B.Sc.; part ii, by F. R. Ennos, B.A., B.Sc., A.I.C., *Geol. Mag.*, vol. lix, 1922, pp. 514–523.

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view to determining the iron content and also the mineral composition. A description of the method employed is given below, together with two examples of the analyses.

The most noteworthy of the five igneous rocks analysed was the Traprain Law phonolite, in which the presence of sodalite, first detected microchemically, was confirmed by the chemical analysis.

Two samples of Welsh and Scottish orthite were obtained from the parent rocks, in a state of high purity, by means of a magnetic separator; the analyses of the minerals are now in progress.

An analysis was made of the Houston Marl, and the composition of the soluble and insoluble portions determined after extraction with acid followed by alkali.

An examination was also made of a method of cement testing on samples supplied by the Building Research Board.

To determine chemically the mineral composition of the sedimentary iron ores a method was devised which enables the carbonates, phosphates, and ferrous aluminium silicates(chamosite, etc.), to be removed by solution, leaving the other minerals unacted upon, (quartz, felspar, mica, clay, haematite or göthite). After numerous trials it was found that, whereas the latter minerals were practically unattacked after treatment with a moderate excess of $\frac{N}{2}$ HCl. at 100° C. for 10 minutes, followed by extraction for 10 minutes with 10 per cent. Na_2CO_3 solution at the same temperature, the iron, calcium and magnesium carbonates and phosphates as well as the ferrous aluminium silicate were completely dissolved. Accordingly, analyses were made of the soluble portions obtained in this way from the various ores. Determinations were also made of carbonate, phosphate, soluble sulphate and ferrous oxide on separate portions of the material by treatment with $\frac{N}{2}$ acid. The insoluble residues were washed, dried and weighed, and kept for microscopic examination.

After satisfying the phosphoric acid and sulphuric acid with lime to form calcium phosphate and sulphate respectively, the remaining lime together with the magnesia was calculated to carbonate; any carbon dioxide left was then assigned to combination with ferrous oxide. The remaining constituents of the soluble portion consisted of ferrous oxide, ferric oxide, alumina and silica. On calculating the percentages of these oxides to molecular proportions and combining the ferric oxide and alumina, the molecules of FeO, $Fe_2O_3 + Al_2O_3$ and SiO_2 were found to be very nearly as 3 : 1 : 2, the ratio in which they occur as chamosite [3 FeO, $(Al\ Fe)_2O_3$, 2 $SiO_2 + nH_2O$]. By this means the presence of chamosite in the ores was proved and the percentage of total oxides of chamosite found. It was not possible to determine the amount of water in the chamosite of the ores as other hydrous minerals were present.

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E. 13702. Lab. No. 697.

Clay Ironstone with heavy ferric ooliths, underlying Lower Lias shale. Top Bed, Yarborough Pit, Frodingham, Lincolnshire.

Lab. No. 714.

Ironstone. Pecten Seam. Upleatham Mine, Marske, Yorkshire.

The percentages given are all calculated on the original rock powder.

Soluble Portion.	Lab. No. 697. Per cent.	Lab. No. 714. Per cent.
SiO_2	4·15	12·13
Al_2O_3	2·98	9·32
Fe_2O_3	1·55	2·71
FeO	10·00	36·45
MnO	·46	·24
CaO	4·47	2·09
MgO	1·93	3·75
P_2O_5	·88	·52
CO_2	6·72	14·16
SO_3	—	·14
Insoluble Residue (dried at 105° C.)	61·39	11·23

Calculated mineral composition of soluble portion :

$Ca_3(PO_4)_2$	1·92	1·13
$CaSO_4$	—	·24
$CaCO_3$	6·13	2·46
$MnCO_3$	·75	·39
$MgCO_3$	4·05	7·88
$FeCO_3$	4·24	23·20

The remaining silicate has the composition :

		Molecular Ratios.		Molecular Ratios.
SiO_2	4·15	2	12·13	2
Al_2O_3	2·98	1·11	9·32	1·07
Fe_2O_3	1·55		2·71	
FeO	7·37	2·96	22·05	3·03
Percentage of total oxides of chamosite in ore	16·05		46·21	

Anal. F. R. Ennos.

21173. Lab. No. 704.

Traprain Law Phonolite. Interior part of Traprain Law Quarry 1-in. sheet 33. 6-in. Haddington 10 N.E.

SiO_2	56·89
TiO_2	·33
Al_2O_3	19·11
Fe_2O_3	2·04
Cr_2O_3	nt. fd.
FeO	3·44
MnO	·18
(CoNi)O	nt. fd.
CaO	2·15
BaO	·01
MgO	·35
K_2O	6·35
Na_2O	6·88
Li_2O	nt. fd.
H_2O at 105° C.	·54
H_2O above 105° C.	1·68

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P_2O_5	·15
FeS_2	·17
SO_3	trace
CO_2	nt. fd.
Cl	·22
	100·49
Less O for Cl	·05
Total	100·44

Anal. F. R. Ennos.

The analysis of the Strathmore Meteorite, which was made in the Survey laboratory in 1921 and published in the *Mineralogical Magazine* in 1922[1], is given below :—

	Attracted by magnet.	Unattracted by magnet.	Bulk-analysis.
Fe	52·60	·29	7·31
Ni	9·05	·05	1·26
Co	·36	—	·05
Fe	1·36	4·29	4·00
S	·78	2·46	2·29
SiO_2	6·34	44·34	40·32
TiO_2	—	·16	·14
Al_2O_3	—	2·89	2·57
Cr_2O_3	—	·50	·44
Fe_2O_3	—	·39	·35
FeO	3·64	14·05	12·99
MnO	nt. fd.	·33	·29
CaO	trace	2·07	1·84
MgO	6·68	27·03	24·96
K_2O	—	·12	·11
Na_2O	—	1·01	·90
H_2O	—	·19	·17
P_2O_5	·08	·25	·23
Cl	—	·03	·03
Insoluble	18·97	—	—
	99·86	100·45	100·25

Composition of the Olivine - 3·27 Mg_2SiO_4 + 1 Fe_2SiO_4.

Mineral composition of the meteorite as calculated from the bulk-analysis and the above composition of the olivine :

$KAlSi_2O_6$	·65		
$NaAlSi_2O_8$	7·64	10·93	Felspar.
$CaAl_2Si_2O_8$	2·64		
$FeO.TiO_2$	—	·27	Ilmenite.
$FeO.Cr_2O_3$	—	·65	Chromite.
$FeO.Fe_2O_3$	—	·51	Magnetite.
$3Ca_3P_2O_8.CaCl_2$	—	·56	Chlor-apatite.
Fe_2SiO_4	12·62		
Mg_2SiO_4	28·51	41·13	Olivine.
$FeSiO_3$	6·63		
$MnSiO_3$	·54		
$CaSiO_3$	2·14	30·91	Bronzite.
$MgSiO_3$	21·60		

[1] W. F. P. McLintock and F. R. Ennos, *Min. Mag.*, vol. xix, No. 98, 1922, pp. 323–329.

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Fe	4·00	6·29	Troilite.
S	2·29		
Fe	7·31	8·62	Nickel-Iron.
Ni	1·26		
Co	·05		
H_2O	—	·17	Water.
	100·04		

Percentage of nickel iron	8·62
Ratio of Fe to Ni in nickel-iron	5·80
Ratio of MgO to FeO in olivine	3·27
" " " pyroxene	4·25
" " " ferromagnesian silicates	3·47

Anal. F. R. Ennos.

V.—PALÆONTOLOGICAL WORK

1. England and Wales

During the preparation of the Sheet Memoirs on the Beaconsfield and Aylesbury districts the assistance of Mr. J. Pringle and Mr. C. P. Chatwin was enlisted. To the first of these memoirs Mr. Pringle contributed a chapter on the underground rocks; in the Aylesbury district an examination of the Jurassic and a part of the Cretaceous rocks was made by these geologists, who wrote the chapters on these formations. Mr. Chatwin also visited the districts of Hertford and Dartford and has been engaged in palæontological work in connexion with the Sheet Memoirs on those areas now in course of preparation.

Mr. Pringle has made visits to the Dorset coast in order to examine certain portions of the Kimmeridge and Portland succession displayed near St. Alban's Head and in the Isle of Portland. He studied in particular a series of clays and sands, above the Pallasianus Zone and below the Portland Stone, which are absent in the Swindon and Aylesbury areas. It has been shown that in those districts the zone of '*Perisphinctes*' *gorei* rests unconformably on a remnant of the Pallasianus Zone.[1] Between these horizons there are present in the neighbourhood of Chapman's Pool, near Kimmeridge, some 240 feet of sands and clays, the ammonites of which have not yet been adequately studied. These beds, exposed in a steep cliff-section, are difficult of access, so that palæontological material from them has hitherto scarcely come under examination. It can now be stated that several ammonite-zones, as yet undefined, are included in this series. Some of the specimens permit close comparison with certain ammonites seen in the cores from the upper part of the expanded Kimmeridge series passed through in the Penshurst boring in Kent. It must be recognised that the fullest developments of

[1] C. P. Chatwin and J. Pringle. 'The Zones of the Kimmeridge and Portland Rocks at Swindon,' in 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 167. *See also* 'The Geology of the Country around Aylesbury and Hemel Hempstead' (*Mem. Geol. Surv.*), 1922 [issued 1923] p. 6.

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the Kimmeridge formation in this country are found in Dorset and underground in the area of the Weald.

Much work has been done by Dr. Kitchin and Mr. Pringle in the final preparation of the memoir on 'The Concealed Mesozoic Rocks in Kent,' written in collaboration with Mr. G. W. Lamplugh. They have included a comparison of the Kimmeridge Clay of Kent with that of the type area in Dorset. The information is set forth in a zonal table in which are recorded the vertical ranges of a number of the commoner and more characteristic fossils of the Kimmeridge series.

Through the kindness of Mr. E. O. Forster Brown, Mr. Pringle has been permitted to visit the site of a deep boring at Adisham, near Canterbury, and to examine the cores of Cretaceous and Jurassic rocks passed through. This boring was still in progress at the end of 1922. Information previously obtained from three borings put down near Southery, Norfolk, forms the subject of an Appendix (p. 126). The results are of considerable stratigraphical interest.

Dr. L. F. Spath visited Folkestone on behalf of the Geological Survey in order to study the Gault succession in detail. The need for a zonal revision in accordance with the progress of modern work had for long been felt. As a result of his field-examinations and the monographic study of the ammonite-fauna of the Gault upon which he has for some time been engaged, Dr. Spath has arrived at important conclusions concerning the zonal classification and has detected and defined the gaps in the sequence at Folkestone. Some of his results have been embodied in a Report published during the year.[2] In continuation of these studies, Dr. Spath has examined the ammonite-faunas and the zonal characters of the deposits below and above the Gault. He deals with this subject in a paper published herewith as an Appendix (p. 139).

Among the fossils added to the collections during the year is a representative suite of specimens from the Bargate Stone, of Upper Aptian age, from localities near Godalming. This comprises many indigenous species as well as a number of rolled and polished specimens derived from the Oxford Clay. Among the Aptian fossils are some fine ammonites and *Nautili;* and particularly noteworthy is a cirripede-capitulum having the plates united in place, a rare state of preservation.

The following specimens in the Museum have been figured or described in publications :—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1920. (PUBLISHED 1922.)

A Monograph of the British Palæozoic Asterozoa. (Part V.)

BY DR. W. K. SPENCER, M.A.

Platanaster ordovicus *Spencer*, pl. xiv, figs. 1, 2, 3, p. 171 (2 specimens).
Palasterina primaeva (*Forbes*), text-fig. 144, p. 203.

[1] L. F. Spath, 'Excursion to Folkestone' *Proc. Geol. Assoc.*, vol. xxxiv, 1923, p. 70.

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A Monograph of the Fossil Insects of the British Coal Measures. (Part ii).

By Mr. H. Bolton, M.Sc., F.R.S.E.

Archimylacris hastata *Bolton*, pl. vii, figs. 1a, b; text fig. 33, p. 104 (2 specimens).
,, obovata *Bolton*, pl. vii, figs. 4a, b; text-fig. 35, p. 110 (2 specimens).
,, sp., pl. vii, figs. 5, 6, pp. 112, 113 (2 specimens).
Phyloblatta sulcata (*Bolton*), pl. viii, figs. 1a, b; text-fig. 36, p. 114 (2 specimens).
Hemimylacris obtusa *Bolton*, pl. viii, fig. 7; text-fig. 38, p. 122.
Orthomylacris lanceolata *Bolton*, pl. ix, fig. 5; text-fig. 43, p. 134.
Archimylacris pringlei *Bolton*, pl. x, fig. 3, p. 146.

In the Annals and Magazine of Natural History, Volume IX, Ninth Series.

The Morphology of some Cretaceous Cirripedes.

By Mr. T. H. Withers.

Scalpellum (Cretiscalpellum) unguis (*J. de C. Sow.*), pl. v, figs. 5, 6, p. 371 (2 specimens).

In the Geological Magazine, Volume LIX.

Notes on the Fauna of the Lower Devonian Beds of Torquay.

By Dr. F. R. Cowper Reed, M.A.

Leiopteria (Actinopteria ?) anisota (*Phill.*), p. 270.
Nuculites (Cleidophorus) subovatus *Reed*, p. 274.
Bellerophon (Pedasiola) *aff.* tumidus (Sandberger) ?, p. 308.

In Type Ammonites, Volume IV.

By Mr. S. S. Buckman.

Tulites subcontractus (*Morris & Lycett*), pl. cclxx, figs. 1, 2, p. 45.
Madarites madarus *S. Buckm.*, pl. cclxxiA, figs, 1, 2; pl. cclxxiB, p. 46.
Bullatimorphites bullatimorphus *S. Buckm.*, pl. cclxxiiA; pl. cclxxiiB, p. 47.
Morrisites morrisi (*Oppel*), pl. cclxxiii, figs. 1, 2, p. 48.
Proplanulites koenigi (*J. Sow.*), pl. cclxxxi, figs. 1, 2, 3, p. 36.
,, lobatus *S. Buckm.*, pl. ccexxx, figs. 1, 1a, 2, 2a, 3, 3a.
,, arciruga *Teisseyre*, pl. ccexxxi, p. 38.
Gowericeras gowerianum (*J. de C. Sow.*), pl. cclxxxvii, figs. 1, 1a, b; pl. cclxxxvii*, figs. 1, 1a, b.
,, ventrale *S. Buckm.*, pl. cclxxxviii.
Galilaciceras trichophorum *S. Buckm.*, pl. ccxci, figs. 1, 2, 2a.
Galilaeanus crucifer *S. Buckm.*, pl. ccxciii, figs. 1, 2.
Galilaeites curtilobus *S. Buckm.*, pl. ccxciv, figs. 1, 2.
Zigzagites imitator *S. Buckm.*, pl. ccci, figs. 1, 2.
Parkinsonites fullonicus *S. Buckm.*, pl. ccccii, figs. 1, 2, 2a; pl. ccccii*, figs. 1, 2, 2a.
Prorsisphinctes omphalicus *S. Buckm.*, pl. ccexxvi, figs. 1, 2, 3.
Homoeoplanulites homoeomorphus *S. Buckm.*, pl. ccexxviii, figs. 1, 1a, 2, 3, 3a.
Trinisphinctes trinus *S. Buckm.*, pl. ccexxxii, figs. 1, 2.
Toricellites approximatus *S. Buckm.*, pl. ccexxxvi, figs. 1, 1a, b, 2, 3, 3a.
Phlyseogrammoceras dispansum (*Lycett*), pl. ccexl.
Suspensites suspensus *S. Buckm.*, pl. ccexlvi, figs. 1, 2.

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Kamptokephalites kamptus *S. Buckm.*, pl. cccxlvii, figs. 1, 2.
Pleurocephalites folliformis *S. Buckm.*, pl. cccxlviii, figs. 1, 2.
Pectinatites pectinatus (*Phill.*), pl. ccclivB, figs. 1, 2, 2a, b, c.
Korythoceras korys *S. Buckm.*, pl. ccclxi, figs. 1, 1a, b, 2, p. 17.

2. Scotland.

In connexion with the revision of the coalfields systematic collecting from Carboniferous sections was prosecuted in the Douglas district and in Ayrshire, while cores from a number of borings in various parts of the country were also examined. A representative collection has been made from the Jurassic Rocks of Ardnamurchan, Argyllshire.

The Carboniferous Invertebrates were dealt with in the Survey Office by Dr. G. W. Lee, and the plants were as usual submitted to Dr. R. Kidston. The materials obtained by Mr. Manson in the Douglas district include a suite of well-preserved *Productus giganteus* (Mart.), collected zonally from two definitely ascertained horizons. These specimens, which obviously belong to the same stock, may provide a step towards the difficult task of recognising evolutionary series in Carboniferous brachiopods. They belong to the typical large, convex and deeply furrowed form. From the evidence at hand it would appear that the species was at its acme during the deposition of the lower stratum (in the 'Prod. giganteus bed'), the specimens from the higher bed in the 'Main Limestone' evincing catagenetic loss of the furrows in the umbonal region. Whether the smaller giganteid *Producti*, occasionally found much higher up in the Index Limestone, are the actual descendants of the form just considered cannot be shown, owing to absence of connecting links; but it is interesting to note that they are quite devoid of furrows and simulate the early giganteids of the Northumbrian Province. Should the phenomenon recorded here prove invariably constant it would furnish a useful means of distinguishing the Main Limestone from the underlying 'Productus giganteus Limestone.' Another *Productus* in which changes, presumably evolutionary, have been observed is *P. latissimus* J. Sow. Here the change would appear to be anagenetic, in the direction of increased spinosity. This change is observable between a form which occurs in the Hollybush Limestone and *P. latissimus* as commonly found much higher up in the Index Limestone.

P. longispinus J. Sow., being one of the commonest of Scottish Carboniferous fossils, would prove an invaluable index-form if a genetic sequence could be established, but the difficulty is to separate the various stocks that go under that name. However, it seems that the most coarsely ribbed of the Scottish forms currently designated '*P. longispinus*' does not occur above the Lower Limestone Series, a point which, if established, would be of practical value.

Further records were obtained of the *Edmondia punctatella* bed below the Calmy Limestone. The occurrence is now known to extend eastwards to the shore of the Firth of Forth.

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As Mr. S. S. Buckman is still engaged on the examination of materials from N.E. Scotland, the ammonites obtained in Ardnamurchan have not yet been submitted to him. Cursory examination in the Survey Office shows, however, that there is a fairly complete sequence from the Lower Lias to the base of the Great Estuarine Series. The Broadford Beds (Sinemurian) at and near Mingary Castle have yielded distinctive ammonites, but the Pabba Shales (Charmouthian) are, unlike their representatives in Mull, poor in recognisable fossils and probably not zonally subdivisible. The small exposures of Scalpa Sandstone (Domerian) offer no features of palæontological interest. The Upper Lias shows a sequence similar to that obtaining in Raasay, and the Ironstone has yielded two species of ammonites not yet known from the Raasay Ironstone. The Inferior Oolite is thicker than in S.E. Mull, and tends towards the Skye type of development. In spite of considerable physical difficulties due to intractability of the baked strata, Mr. Manson was successful in obtaining a number of characteristic specimens. It is probable that critical study will reveal the presence of several zones, possibly from *scissum* to *blagdeni*. The attribution to the Estuarine Series of a thin outcrop of black shales rests on the presence of a large *Estheria* referred to *E. murchisonae* Jones, a species founded on specimens from the Estuarine Series of Skye.

A fish-tooth, probably derived, found in association with a coaly deposit in Ardnamurchan, was submitted to Dr. A. Smith Woodward, who stated it to show resemblance to the Upper Cretaceous *Oxyrhina mantelli* Ag.

VI.—MUSEUM OF PRACTICAL GEOLOGY

The exhibits of British economic minerals and rocks have continued to increase and special attention has been paid to fireclays, abrasives, silica rocks, roadstones and iron ores. The collection of building stones has been cleaned and in part revised. The recent work of the Survey is now illustrated in a special case containing typical Survey maps, memoirs and other publications, whilst the latest edition of the quarter mile map of England and Wales has been mounted and is now exhibited on one of the walls.

A new edition of the Short Guide to the Museum has been issued.

The Strathmore meteorite has been examined petrographically and chemically and the results published.

A large number of enquiries has been dealt with in the Museum, the Library and Map Room and considerable time has been occupied in dealing with a growing demand on the part of schools, scientific societies and clubs for demonstrations in the Museum.

The examination of the English and Welsh Iron Ores has been continued. By means of a series of analyses of which an outline has been given on p. 117, it has been shown that the chloritic

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mineral chamosite, with the formula $2SiO_2$, Al_2O_3, $3FeO$, aq., is an essential constituent of the Cleveland and Frodingham ironstones. This mineral represents the 'green silicate' of uncertain composition to which the excess of ferrous iron has in the past been assigned. Apart from a small amount of glauconite this would appear to be the only ferrous silicate present in the ordinary bedded ores, and it may be anticipated that the analysis of the Marlstone and Northampton ores will yield similar results. The chamosite occurs in part as ooliths and as distinct crystalline flakes, but mainly as an aggregate of minute flakes parallel with the bedding, and at times is apparently amorphous. A variable but usually small residue, insoluble in the acid used, consists of non-ferruginous clay substance, quartz grains, &c., and mainly represents accidentally derived material from the adjoining shale or sandstone facies. Chamosite is present in the normal Lower Lias shale at Frodingham, and in the Cleveland interbedded shale. The distinction between the iron ore and the adjoining rocks consists in the relative subordination of the detrital constituents and the dominance of the chemically precipitated minerals chamosite and siderite. Carbonation of the chamosite mud is an almost universal feature, no doubt resulting from the decomposition of dead organic matter below the exposed surface. It is to this carbonation that the value of the ore is mainly due, for the presence of very little additional silica is sufficient to make a pure chamosite ore commercially valueless.

The Frodingham mudstone and limestone contain ooliths composed of nearly pure hydrated ferric oxide Fe_2O_3, H_2O. These are brown in thin sections, and have a radial-fibrous and concentric structure analogous with that of chamosite ooliths. Similar ooliths occur at Claxby and in the Kentish iron ores.

On the whole the present results indicate that the bedded ores are substantially in the condition in which they were deposited, the only 'secondary' alteration of general importance being the carbonation of chamosite during the period of cementation. Calcite in shells is generally well preserved and is very rarely replaced by siderite. This is of special interest in view of the opinion, once widely quoted, that ores such as the Cleveland ironstone result from the replacement of oolitic limestones.

The maximum carbonation of an unweathered marine ironstone was observed in the Cleveland 'Dogger Stone' which contained only 15 per cent. of chamosite with 52 per cent. of siderite. It is of great interest to note that the analyses of the Coal Measure ironstones in the 'Iron Ores of Great Britain' indicate that these rocks contain no chamosite. This corresponds with the conditions of strong carbonation obtaining during their deposition, and probably is an equally characteristic difference between the associated shales and those of formations such as the Lias.

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APPENDIX 1

On the Concealed Mesozoic Rocks in South-West Norfolk

By J. Pringle

Introduction

During the year 1920, three boreholes were drilled in the Fen lying to the east of Southery, and the results of two of these undertakings yield much information concerning the underground range of the Jurassic rocks beneath the Cretaceous formations in the south-west corner of Norfolk. At the same time the borings reveal important facts regarding the Lower Cretaceous strata, and throw some light on the movements and denudation of these rocks prior to the deposition of the Upper Gault.

Unfortunately, the cores obtained from the borings were of the narrow diameter of 2 inches, but this handicap was to some extent lessened by the fossiliferous character of many of the formations, and the finding of numerous specimens of zonal value. These have served as valuable guides in estimating the thickness of each formation passed through. I have to acknowledge the able assistance of Mr. A. Templeman in collecting the fossils, and to thank Mr. S. S. Buckman for some help in the naming of the ammonites.

The chief results of the deepest boring may be summarized as follows :—

(1) The Chalk appears to pass conformably downwards into the Upper Gault.

(2) The base of the Upper Gault rests unconformably on the basement-beds of the Sandringham Sands, which in turn lie unconformably on the Kimmeridge Clay.

(3) From the local top of the Kimmeridge Clay down to the base of the Oxford Clay there appears to be a complete sequence, so far as can be ascertained. All of the formations are remarkably thin, particularly the Kimmeridge Clay, which, although nearly completely represented, is only 125 feet thick in this boring. The Kellaways Rock appears to be absent.

(4) The Forest Marble rests unconformably on the Marlstone of the Middle Lias. This boring was stopped in the Lower Lias without proving the full thickness of the subdivision.

The lithological characters of the Lower Lias are not unlike those of the corresponding beds at the outcrop throughout the Midlands. The subdivision consists mainly of fine clays with hard calcareous rock-bands. Beds of coarse sediment are absent, and consequently there is no indication of the close proximity of the ridge of Palæozoic rocks proved in the Culford boring.

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Although it is now clear that deeper water prevailed in the area north of Culford, the sections suggest that the Jurassic formations soon wedge out eastwards on a rising slope of Palæozoic rocks. Indeed, the results of the borings amply confirm the observations of Mr. G. W. Lamplugh, who has pointed out that the Jurassic rocks 'as a whole have their greatest thicknesses and fullest sequence in the west and become attenuated by gaps and unconformities eastwards,'[1] Clearly this remark can be extended to include the Lower Cretaceous strata and the whole of the Lower Gault in West Norfolk and elsewhere. We can thus recognize the stratigraphical unity of the Upper Gault with the overlying Cenomanian. The term Upper Gault as here used must be taken to include the Junction Bed VIII of Folkestone as its base. The behaviour of these upper beds of the Gault, showing as they do, transgressive extensions over wide areas in this and other countries,[2] emphasizes the value of Prof. Barrois's classification which brought out the stratigraphical connexion between the Upper Gault and the overlying Chalk.

The Sections.

(A.) Boring at Decoy Farm about 1¾ miles E. of Southery, Norfolk. One inch New Series Ordnance Map 173; Old Series Geological Map 65. Height above Ordnance Datum about 5 feet.

		Thickness. Ft.	in.	Depth. Ft.	in.
Alluvium. (No cores, samples only).	Black peaty surface soil	1	6	1	6
	Yellowish sandy clay	9	6	11	0
	Bluish clayey sand	11	9	22	9
	Fine bluish-black sand with clay ...	17	3	40	0
Kimmeridge Clay	Black shelly clay with numerous bands of greenish-black oil-shale. *Saccocoma sp.*, *Lucina minuscula* Blake at 40½ ft.	26	1	66	1
	Dark shale with iron pyrites	0	0¾	66	1¾
	Black shelly clay with ½-inch band of cement stone at 82¼ ft. *Exogyra virgula* (Defr.), *Protocardia morinica* (de Lor.), and *Amoeboceras krausei Salfeld* numerous at base	26	4½	92	6
	Brownish-black inferior oil-shale with layers of finely comminuted ammonite-shells	1	9	94	3
	Black shelly clay	11	9	106	0
	Cement stone	2	0	108	0
	Black clay with some pale calcareous rock-bands. *Exogyra virgula* (Defr.) and *Rasenia sp.* at 136 ft.	31	6	139	6
	Cement stone	1	0	140	6

Bottom of boring at 140½ feet.

[1] G. W. Lamplugh, 'The structure of the Weald and Analogous Tracts,' *Quart. Journ. Geol. Soc.*, vol. lxxv, p. lxxxvi, 1920.

[2] See F. L. Kitchin and J. Pringle, 'On the Overlap of the Upper Gault in England and on the "Red Chalk" of the Eastern Counties,' *Geol. Mag.*, vol. lix, 1922.

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(B.). Boring on Methwold Common, about 3½ miles E. of Southery, Norfolk. One-inch New Series Ordnance Map 173; Old Series Geological Map 65. Height above Ordnance Datum 7 ft.

		Thickness. Ft.	in.	Depth. Ft.	in.
Superficial Deposits	Peat	13	9	13	9
	Fine white sand...	1	3	15	0
	Coarse sand with small flint pebbles ...	15	0	30	0
Gault 36 ft.	Fine sandy clay...	21	0	51	0
	Fine white clay with many chalk-like pellets	15	0	66	0
	Unconformity.				
Lower Greensand	Hard greyish-brown gritty glauconitic sand-rock with small phosphatic nodules; iron pyrites at base ...	1	4	67	4
	Unconformity.				
Kimmeridge Clay 121 ft. 1 in.	Black shelly clay with numerous bands of greenish-black oil-shale. *Saccocoma sp. Lucina minuscula* Blake, *Ostrea sp.* and Fish remains ...	22	8	90	0
	Black shelly clay with thin inferior oil-shale in places. Many layers of fine 'shell-dust'	52	0	142	0
	Cement stone	1	0	143	0
	Black shelly clay with *Exogyra virgula* (Defr.)...	9	0	152	0
	Pale and dark shelly clays	7	5	159	5
	Cement stone	0	4	159	9
	Bluish-grey clay with *Involuticeras* cf. *desmonotus* (Opp.)	12	5	172	2
	Cement stone	0	4	172	6
	Bluish-grey clay with *Exogyra virgula* (Defr.)...	8	6	181	0
	Grey limy shelly clay with fragments of large ammonites, *Pictonia* ?, and *Pholadidea sp. nov.* ?	7	5	188	5
Corallian (Ampthill Clay) 50 ft. 9 in.	Pale grey compact limestone	0	10	189	3
	Bluish-grey limy clay, becoming darker below. *Amoeboceras serratum* (J. Sow.) at 212 ft. and *Protocardia delibata* (de Lor.)...	30	4	219	7
	Pale smooth claystone	0	3	219	10
	Grey marly clay	2	5	222	3
	Pale smooth compact limestone ...	0	6½	222	9½
	Grey marly clay with a 3-inch band of pale compact limestone at 226 ft. 3 in.	7	5	230	2½
	Pale grey compact limestone	0	7½	230	10
	Grey marly clay with *Alaria sp.* ...	8	4	239	2
	Soft black clay (cores imperfect) ...	20	10	260	0
	Soft smooth grey clay	3	3	263	3
	Pale smooth compact claystone ...	1	0	264	3
	Smooth dark clays (cores badly broken); *Quenstedtoceras sp.* at 270½ ft.	13	6	277	9
	Pale compact grey limestone	0	5	278	2
	Dark grey marly clay	2	4	280	6
	Pale grey limestone	0	3	280	9
	Soft black clay	2	7	283	4
	Pale grey fine-grained limestone ...	0	10	284	2

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		Thickness. Ft.	in.	Depth. Ft.	in.
Oxford Clay 159 ft. 4 in.	Soft grey clay	5	0	289	2
	Pale grey fine-grained limestone ...	3	7	292	9
	Dark grey marly clay	3	6	296	3
	Pale grey fine-grained limestone ...	0	3	296	6
	Black shaly clay; *Grammatodon sp.* ...	7	6	304	0
	Soft greenish-brown clay with *Quenstedtoceras sp.*, *Pinna* cf. *mitis* Phill. ...	5	9	309	9
	Grey earthy limestone	0	3	310	0
	Greenish-grey marly clay with numerous specimens of *Quenstedtoceras*	13	6	323	6
	Grey earthy limestone	0	6	324	0
	Soft black clay with some hard bands; *Alaria trifida* Phill.	12	6	336	6
	Pale grey shelly clay with two hard bands; *Quenstedtoceras* cf. *lamberti* (J. Sow.), *Pinna mitis* Phill. at 337 ft.	17	0	353	6
	Greenish tinged brownish-grey marly clay with some hard calcareous bands; *Cosmoceras* cf. *jason* (Rein.), *Cosmoceras* cf. *stutchburii* (Pratt), *Perisphinctes* cf. *comptoni* (Pratt), *Cucullaea sp.*, *Gryphaea* cf. *bilobata* J. de C. Sow., *Pseudomonotis sp.*, and *Serpula vertebralis* J. de C. Sow	40	6	394	0
	No core	4	6	398	6

Bottom of Boring 398½ ft.

(C.). Boring, 1 mile N.E. of Severals House, 4½ miles E.N.E. of Southery. One-inch New Series Ordnance Map 159; Old Series Geological Map 65. Height above Ordnance Datum about 10 feet.

		Thickness. Ft.	in.	Depth. Ft.	in.
Superficial Deposits	Soil and crumbly peat	2	0	2	0
Lower Chalk 38 ft.	Soft white chalk with some fine grains of glauconite	30	0	32	0
	Greyish-white finely glauconitic sandy marl with a hard chalk-band, 1 ft. thick, at 38 feet. Numerous specimens of *Ostrea canaliculata* (J. Sow.)	8	0	40	0
Gault 59 ft. 8½ in.	Bluish-grey clay, drying almost white, *Inoceramus sulcatus* Park. and *Belemnites minimus* List. in lower part ...	34	0	74	0
	Soft bluish clay with many chalk-white pellets	25	8½	99	8½
	Unconformity.				
Lower Greensand 3 ft. 0½ in.	Hard grey sandrock with numerous grains of glauconite and small well-rounded black phosphatic nodules ...	0	3½	100	0
	Brownish-grey muddy sand with brown rusty specks	2	0	102	0
	Hard dark grey sandrock with numerous grains of glauconite and small well-rounded black phosphatic nodules. Iron pyrites abundant in matrix at base	0	9	102	9

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		Thickness. Ft.	in.	Depth. Ft.	in.
	Unconformity.				
Kimmeridge Clay 125¼ ft.	Black shelly clay with numerous beds of greenish-brown oil-shale; *Saccocoma* at 119 ft. 9 in. with *Lucina minuscula* Blake, etc.	25	9	128	6
	Brownish-grey shale with *Modiola autissiodorensis* (Cott.)	3	3	131	9
	Grey cement stone	0	8	132	5
	Black shelly clay with thin impure oil-shales; *Exogyra virgula* (Defr.) at 134 ft....	10	7	143	0
	Soft black shelly clay with numerous specimens of *Amoeboceras krausei* Salfeld at 162½ ft. and *Lingula ovalis* J. Sow...	36	2	179	2
	Hard limy clay	0	6	179	8
	Soft black shelly clay with a grey cement stone, 10 inches thick, *Protocardia morinica* (de Lor) ...	2	0	181	8
	Bluish grey shelly clay with a 3-inch band of earthy limestone; *Rasenia* cf. *phorcus* (Fontannes), *Involuticeras* cf. *desmonotus* (Opp.) between 208 ft. and 210 ft.	30	8½	212	4½
	Grey bituminous limestone	0	6	212	10½
	Black shaly clay with bands of soft lumpy clay; *Rasenia sp.* at 215 ft....	9	1½	222	0
	Pale grey limy clay with fragments of large smooth ammonites, *Pictonia?*	6	0	228	0
Corallian (Ampthill Clay) 52 ft. 1 in.	Soft black shelly clay	3	2	231	2
	Grey earthy limestone	0	10	232	0
	Dark grey shelly clay with *Amoeboceras* cf. *serratum* Salfeld at 247 ft. ...	21	0	253	0
	Pale claystone	0	4	253	4
	Soft dark grey clay	10	6	263	10
	Grey clayey limestone	0	8	264	6
	Crumbly grey clay with *Cardioceras sp.*	3	9	268	3
	Hard pale claystone with *Cardioceras sp.*	0	6	268	9
	Soft grey clay	3	5	272	2
	Pale compact earthy limestone ...	0	11	273	1
	Grey slate-coloured clay with *Cardioceras sp.* at 277 ft.	7	0	280	1
	Grey clay (much core lost in passing through this bed)	21	4	301	5
	Pale grey limestone	0	11	302	4
	Grey marly clay	4	10	307	2
	Pale grey limestone	0	4	307	6
	Smooth bluish-black clay	12	6	320	0
	Grey compact limestone with marly parting	2	0	322	0
	Soft dark clay	9	6	331	6
	Grey earthy limestone	1	0	332	6
	Soft dark sandy clay	4	0	336	6
	Grey limestone	0	6	337	0
	Dark grey clay	7	6	344	6
	Grey limestone	0	6	345	0
	Pale grey limy clay with a few hard calcareous bands; *Quenstedtoceras*				

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		Thickness. Ft.	in.	Depth. Ft.	in.
Oxford Clay 199 ft. 5 in.	*sp.* (finely ribbed) at 350 ft., *Eboraciceras ordinarium*? (Bean-Leck.) at 382 ft., and *Grammatodon concinnus* (Phill.)...	61	0	406	0
	Greenish and brownish-green sandy clay	39	0	445	0
	Pale fine grained limestone	1	0	446	0
	Soft brownish clay	8	3	454	3
	Smooth pale grey claystone	1	9	456	0
	Hard brownish shelly clay with thin bands of earthy limestone; *Cosmoceras stutchburii* (Pratt)	1	3	457	3
	Soft dark grey finely micaceous clay with a hard limy band at base; *Nuculana phillipsi* (Mor.), *Cosmoceras jason* (Rein.), and *C. stutchburii* (Pratt)	17	9	475	0
	Dark clayey sand, estimated thickness	3	0	478	0
	Brownish-grey sandy marl with *Gryphaea sp.*, *Pseudomonotis sp.* and *Cosmoceras sp.*	1	6	479	6
	Unconformity.				
Cornbrash? and Forest Marble 10 ft.	Hard bluish-grey non-oolitic limestone	2	0	481	6
	Dark shelly clay with *Ostrea sowerbyi* Morr. & Lyc.	0	6	482	0
	Hard bluish-grey limestone earthy in places	3	3	485	3
	Black and greenish-black shelly clay with a thin band of grey limestone; Lignite etc.	4	3	489	6
	Unconformity.				
Middle Lias 38½ ft.	Soft greenish sandy marl with a greenish gritty band and knobs of grey limestone	2	6	492	0
	Green tinged marly limestone with brown rusty specks, and a fragment (pebble?) of brownish-grey oolitic limestone. *Belemnites sp.*	1	6	493	6
	Soft grey micaceous sandy clay, green-tinged at top. At base, clay is hard and contains pebble-like concretions. *Lima pectinoides* J. Sow., *Cardinia sp.* and *Unicardium*?	9	6	503	0
	Smooth grey clay with a 4-inch band of brown limestone; *Amaltheus sp.* at 318 ft....	25	0	528	0
Lower Lias 142 feet	Dark grey shelly micaceous clay with thin limestone bands. *Aegoceras* cf. *lataecosta* (J. de C. Sow.) at 530 ft.	23	8	551	8
	Bluish-grey shelly limestone, with a thin clayey band	2	4	554	0
	Soft black clay with several thin bands of clayey limestone; *Nuculana sp.* (B.)	41	0	595	0
	No cores between 595 feet and 634 feet [said to be clay]...	39	0	634	0
	Black clay	0	6	634	6

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	Thickness. Ft.	in.	Depth. Ft.	in.
No cores between 634½ feet and 644 feet [clay]	9	6	644	0
Dark grey earthy limestone with *Rhynchonella* cf. *rostellata* (Quenst.) ...	2	0	646	0
Black clay with numerous specimens of *Nuculana sp.* (B.)...	24	0	670	0

Bottom of boring 670 feet.

Notes on the Cretaceous and Jurassic Rocks.

Lower Chalk. The lower part of this subdivision was passed through in the Severals House boring, and the details set forth in the section represent practically all the information that could be gleaned from a study of the cores. Towards the base of the Chalk, the marl is sandy and glauconitic as in the Stoke Ferry boring,[1] but no phosphatic nodules were found. The lower beds yielded specimens of *Ostrea canaliculata* (J. Sow.).

Gault. It is well known that the Gault undergoes marked changes in lithological characters and in thickness in passing northwards under the alluvium of the Fenland. Recently,[2] it has been pointed out that these changes are due to the fact that the Upper Gault has overlapped the Lower Gault. The Upper Gault is seen to become thinner and to rest unconformably on various members of the Lower Greensand when traced northwards to Hunstanton, where it forms a major part of the "Red Chalk." The transgression appears to have been accompanied by considerable erosion of the underlying beds, and as noted in the Methwold and Severals House borings, only a remnant of the basement beds of the Sandringham Sands is present at these localities. This does not necessarily imply that the erosion at the time of the Upper Gault transgression was responsible for the whole of this denudation of the Lower Greensand and the Lower Gault. It is highly probable that much of the Sandringham Sands had already been removed prior to the deposition of the Mammillatus Bed since this bed and associated sands are found to rest non-sequentially on a horizon low down in the Sandringham Sands in another boring to the north, a record of which has not yet been published. In the result, the great bulk, if not the whole of the Lower Cretaceous series of North Norfolk and of Lincolnshire, is absent in this district. The evidence of the borings, here described, confirms the statement made elsewhere,[3] that the Lower Gault and Mammillatus Bed of West Dereham is an isolated occurrence.

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[1] A. J. Jukes-Browne and W. Hill, 'On the lower part of the Upper Cretaceous series in West Suffolk and Norfolk,' *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 556.

[2] F. L. Kitchin and J. Pringle, 'On the Overlap of the Upper Gault in England and on the "Red Chalk" of the Eastern Counties,' *Geol. Mag.*, vol. lix, 1922, pp. 156–166, 194–200.

[3] *Op. cit.*, pp. 166, 199.

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In the Severals House boring the Lower Chalk passes down imperceptibly into the Upper Gault. The clay, which becomes nearly white after exposure, yields amongst other fossils, *Inoceramus sulcatus* Park. This shell is characteristic of Beds VIII and IX of Folkestone, and has been found at various localities along the outcrop to the north of West Dereham. Unfortunately, the downward range of the shell could not be tested in this boring as the clay, which contains abundant small chalk-white pellets in the lowest 30 feet, was so fragile that few cores were secured. A similar bed at the base of the Gault was passed through in the Methwold boring, but no attempt was made to secure a core. The thickness of the Upper Gault in the Severals House section is almost the same as that of the Gault recorded in a boring at Stoke Ferry.[1]

Lower Greensand. The beds referred to this formation are identical with those forming the basement beds of the Sandringham Sands at the outcrop around North Runcton Church,[2] and passed through in many of the borings made in search of oil-shale in the area lying between the Wissey and the Gaywood rivers.[3] The numerous black phosphatic nodules which are incorporated in the basement-beds appear to have been derived from the underlying Kimmeridge Clay. Some of them show obscure traces of ammonites. Iron pyrites is abundant in the matrix of the lowest layer of the sand. These nodules are not sandy, and in this respect differ from the phosphatized arenaceous nodules found in the Mammillatus Bed at West Dereham and elsewhere.[4]

Kimmeridge Clay. This formation was penetrated in each of the three borings, but its full thickness was only proved in the Methwold and Severals House sections. It consists mainly of dark clays with a few bands of grey argillaceous limestone and brown and greenish-brown oil-shales. These oil-shales are best developed in the upper part of the series. The Kimmeridge Clay of this district as exhibited in the cores of these borings is remarkably thin when contrasted with the thickness of the formation as exposed in the type area of Dorset, where it is estimated to be between 1,100 and 1,300 feet thick north of Weymouth.[5] The marked thinness of the formation appears to to have been the result of slow deposition and not to be due to the non-representation of beds through the existence of non-

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[1] W. Whitaker, 'The Water Supply of Norfolk' (*Mem. Geol. Surv.*), 1921, p. 121.

[2] 'The Geology of South Western Norfolk and of North Cambridgeshire' (*Mem. Geol. Surv.*), 1892, p. 17.

[3] J. Pringle, 'Note on the Lower Greensand in the West Bilney borehole, Norfolk,' in 'Summary of Progress of the Geological Survey for 1919' (*Mem. Geol. Surv.*), 1920, p. 65.

[4] 'The Cretaceous Rocks of Britain' (*Mem. Geol. Surv.*), vol. i, p. 298; *see also* J. J. H. Teall, 'The Potton and Wicken Phosphatic Deposits' (Sedgwick Prize Essay for 1873), 1875, pp. 20–22.

[5] 'On the Thicknesses of Strata in the Counties of England and Wales' (*Mem. Geol. Surv.*), 1916, p. 49.

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sequences. No stratal breaks were detected during the examination of the cores. Indeed, the Kimmeridge zonal sequence established by Salfeld,[1] and amplified later by Kitchin and Pringle[2], appears to be completely represented so far as could be tested, excepting part of the uppermost zone. It is highly probable that the ridge of Palæozoic rocks which lay to the eastwards was submerged, and did not contribute to the accumulation of sediment.

The condensed character of the sequence is clearly brought out by a number of facts of different values. Thus, the radial plates of the free-swimming crinoid, *Saccocoma*, which characterize the ' Blackstone ' of Kimmeridge Bay and the ' Main Bed ' of Corton, have a vertical range of 13 feet in the greatly expanded series in Dorset. In the borings here described this fossil is confined to a bed less than one foot thick. Similarly, the shells referred to *Involuticeras desmonotus* (Oppel), which are found elsewhere in great abundance in the lower part of the Zone of *Rasenia mutabilis*, occupy an exceedingly narrow band in the cores of the Methwold and Severals House borings. Again, evidence of slow accumulation of sediment is to be found in the marked absence of large uncrushed shells and in the great abundance of bivalve-shells of small dimensions, such as *Lucina minuscula* Blake and several species of *Astarte*, while on some levels the shales are characterized by layers of fine ' shell-dust,' consisting mainly of opalescent fragments of ammonite shells which had broken down before entombment had taken place.

It is highly probable that the basement-bed of the Sandringham Sands rests on a level within the lower part of the Pallasianus Zone in the Methwold and Severals House borings. The clay passed through between the depths of 103 feet and 107 feet in the Severals House section yielded fragments of a ' *Perisphinctes* ' which is closely comparable with certain shells commonly found in the lower part of this zone in Dorset. Better preserved ammonites obtained from the cores of a boring near King's Lynn give weighty support to this correlation. It is of interest to note, therefore, that the Sandringham Sands in Norfolk rest unconformably on the same horizon as that on which the Spilsby Sandstone is found in the Donnington Borehole in Lincolnshire.[3]

The lower part of the underlying Pseudovirgatites zone is conspicuously represented in each of the borings by the subzone of *Saccocoma*. The pyritized radial plates of this free-swimming crinoid were found in abundance, and in the Severals House section it was noted that the vertical range of the genus was

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[1] H. Salfeld, ' Certain Upper Jurassic Strata of England,' *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, pp. 423–432.

[2] G. W. Lamplugh, F. L. Kitchin, and J. Pringle, ' The Concealed Mesozoic Rocks in Kent ' (*Mem. Geol. Surv.*), 1923, pl. ii.

[3] J. Pringle, ' Palæontological notes on the Donnington Borehole of 1917,' in ' Summary of Progress of the Geological Survey for 1918 ' (*Mem. Geol. Surv.*), 1919, pp. 50–52.

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8 inches. In the Methwold and Decoy borings it characterized a band of shale about one foot thick. *Saccocoma* also occurs abundantly in the so-called Puny Drain shales of the Setch district, and it has proved to be a useful datum-guide in the majority of the borings in the Kimmeridge Clay throughout Norfolk. The other constituents of the fauna present in abundance are *Lucina minuscula* Blake, *Ostrea bononiae* Sauvage, and fish-remains. The Zone of *Virgatites* is not well defined in the Decoy and Methwold sections, but at Severals House, where the base of the zone is taken at a cement-stone penetrated at a depth of 132 feet, it is 10 feet in thickness. This rock-band is clearly on the same stratigraphical horizon as the Yellow Ledge of Kimmeridge Bay, where it forms the base of the Virgatites Zone and the top of the Zone of *Gravesia gravesi*. In Norfolk, as in Dorset, the cement-stone marks the limit of the upward range of *Exogyra virgula* (Defr.), while the overlying shales contain early forms of *Modiola autissiodorensis* (Cott.). The lower limit of the Gravesia Zones was not determined, but it must lie between the depths of 143 feet and 162 feet in the Severals House section. At 162 feet from the surface, the Zone of *Aulacostephanus pseudomutabilis* is indicated by the presence of *Amoeboceras krausei* (Salfeld). This ammonite is frequently found in association with *Aulacostephanus eudoxus* (d'Orb.), and appears to be closely related to certain shells formerly, though wrongly, referred to *Ammonites kappfi* Oppel from this zone in Kimmeridge Bay. The clay which probably represents the lower Aulacostephanus Zone failed to yield ammonites in any of the borings.

The Zone of *Rasenia mutabilis* is well shown in all of the sections by the occurrence of *Involuticeras desmonotus* (Oppel) and other closely allied forms. These shells are also characteristic of the lowest beds of the Kimmeridge Clay in the Roslyn Hill pit, near Ely. In the Dover section, similar species occur at a height of about 45 feet above the top of the Corallian.[1] In south-west Norfolk, in a more attenuated sequence, they are found in abundance about 18 feet above the base of the Kimmeridge Clay, and have proved to be a most useful datum-guide in all of the sections. The beds which probably represent the underlying Zone of *Rasenia cymodoce* did not yield any ammonites. Numerous specimens of *Rasenia stephanoides* (Oppel) have, however, been collected from the clays of this zone in several borings near King's Lynn.

In the Methwold and Severals House sections the grey limy clay at the base of the formation contained fragments of smooth ammonites, which, Mr. S. S. Buckman suggests, might be referred to the genus *Pictonia*. Although, owing to the size of the cores, the fragments are too small for us to be certain of this identification, it is thought likely that the bed falls within the Pictonia Zone.

[1] G. W. Lamplugh and F. L. Kitchin, 'On the Mesozoic Rocks in some of the Coal Explorations in Kent' (*Mem. Geol. Surv.*), 1911, p. 116.

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Corallian. As might be expected, the sequence of the Corallian rocks is nearly identical in the two borings. The formation is mainly represented by clays of Ampthill type, containing in the lower portion several thin bands of smooth compact limestone. In the Severals House section a soft black shelly clay, which was absent in the Methwold boring, is shown as forming the top of the Corallian; it is possible, however, that this is due to a reversal of core, a matter of common occurrence during boring-operations.

At about 24 feet below the top of the formation in both borings, the clays yielded several specimens of *Amoeboceras serratum* (J. Sow.), which indicate the Zone of *Perisphinctes decipiens* of Salfeld's classification. In the Methwold boring the ammonites were accompanied by *Protocardia delibata* (de Lor.), which is a common shell on horizons in France corresponding with our uppermost Corallian and Lower Kimmeridge Clay. The thin bands of limestone in the lower part of the formation probably occupy a position corresponding to that of the Elsworth Rock, but they do not show any of the characteristic features of that well-known rock-band. In the clay at the base of the formation in the Severals House section, a young specimen of *Cardioceras* was found at the depth of 277 feet. This ammonite, although it remains specifically undetermined, strongly suggests the presence of the Scarburgense Zone of Mr. S. S. Buckman's classification.[1] This zone, which, at least in part, replaces the 'Pre-*cordatum* Zone' of Mr. Buckman, is now assigned by him to the Argovian stage when that name is employed to comprise the strata which are distinguished by the presence of *Cardioceras*. The thickness of the Corallian in the Methwold and Severals House sections is nearly the same as that of the corresponding beds proved in the Stretham boring.[2]

Oxford Clay. Lithologically, the beds comprised under this heading fall into two parts: an upper, consisting mainly of black and grey clays with subordinate bands of limestone, and a lower, which is largely made up of green-tinged brownish-grey clays and sandy marls. The higher beds were poorly fossiliferous, and yielded only a few fossils mostly in a fragmentary condition. These included several unidentified species of *Quenstedtoceras*, one of which was found on a horizon about 31 feet below the top of the formation in the Methwold section. The lower beds, on the other hand, were highly fossiliferous, and probably fall wholly within the Ornatus subdivision of the Oxford Clay, in the broad sense. The lithological characters of the clays are closely similar to those of the zone as shown in the Kentish borings.

In the absence of determinable fossils of zonal significance, it is assumed that the Zone of *Quenstedtoceras mariae* is represented

[1] *See* 'The Geology of the Country between Whitby and Scarborough' (*Mem. Geol. Surv.*), 1915, pp. 60 and 87.

[2] T. Roberts, 'The Jurassic Rocks of Cambridge,' 1892, pp. 23, 24, 47, 65.

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by some portion of the higher clays. In most borings fossils prove to be somewhat rare in these upper beds of the Oxford Clay. The underlying Renggeri Zone, however, is indicated in the Methwold and Severals House sections. The specimen assigned to *Quenstedtoceras* cf. *lamberti* (J. Sow.), which was kindly examined by Mr. S. S. Buckman, was found at the depth of 337 feet in the Methwold boring, and it is closely comparable with similar shells from the Renggeri Zone in the Ludgershall railway-cutting, near Bicester. The shell is preserved in bright pyrites. The same horizon is shown in the Severals House boring by the occurrence of *Eboraciceras ordinarium*? (Bean-Leck.) at the depth of 382 feet, where it is associated with *Grammatodon concinnus* (Phill.).

The top of the Ornatus Beds was reached at about the depth of 353½ feet in the Methwold section, but the boring stopped before proving the full thickness of the subdivision. At Severals House these beds were entered at the depth of 406 feet, and were found to be 73½ feet thick. They were highly fossiliferous, and some of the more important species are given in the detailed sections set forth on p. 129. In the lowest bed of this subdivision in the Severals House borehole, a fragment of a *Cosmoceras* having some resemblance to *C. elizabethae* (Pratt) was found. It is likely, therefore, that the Kellaways Rock has no representation, since the underlying rock-band is probably of Cornbrash age. All of the formations which remain to be described were passed through in the Severals House boring.

Cornbrash and Forest Marble. The 2-foot band of hard grey non-oolitic limestone penetrated at the depth of 479½ feet, is referred doubtfully to the Cornbrash in the absence of characteristic fossils. The rock-band compares closely with a similar limestone containing *Macrocephalites* in the Westbury boring.[1] The lithological features of the Forest Marble are identical with those which characterize the formation in its underground range in Kent, and the greenish-black colour of some of the lower clays is similar to that displayed by a portion of the corresponding beds in the Blackthorn Hill railway-cutting, near Bicester. The following fossils, mostly in a poor state of preservation, were collected :—Lignite, *Rhynchonella sp.*, *Astarte sp.*, *Modiola sp.*, *Ostrea sowerbyi* Morris and Lycett, and *Pecten* (*Chlamys*) *vagans*? J. de C. Sow. No pebbles were found at the base, which rests on a fresh unweathered surface of Middle Lias. Although the existence of a non-sequence between the Forest Marble and the Great Oolite in the railway-cuttings near Bicester has been pointed out,[2] this appears to be the first instance in

[1] J. Pringle, 'On a boring for coal at Westbury, Wiltshire,' in 'Summary of Progress for 1921' (*Mem. Geol. Surv.*), 1922, p. 147.

[2] A. M. Davies and J. Pringle, 'Two deep borings at Calvert Station,' *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, p. 316.

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England where the Forest Marble is found to rest directly on the Middle Lias.

Lias. The green-tinged marly limestone entered at the depth of 489½ feet in the Severals House boring clearly belongs to the Marlstone of the Middle Lias. Specimens of the rock so closely resemble those taken from the lower part of this sub-division in the Folkestone boring[1] that they are only separable by means of their labels. The only fossils found were fragments of *Belemnites*. The underlying soft grey micaceous clay, which possibly represents the upper part of the Margaritatus Zone, was more highly fossiliferous, and yielded *Cardinia sp.*, *Gryphaea ?*, *Lima pectinoides* J. Sow., *Protocardia sp.* and *Unicardium ?*. The thick bed of soft grey clay at the base contained several specimens of a juvenile form of *Amaltheus* at the depth of 518 feet. Mr. S. S. Buckman, who has examined the shells, states that they indicate the lowest Middle Lias clays as developed just above the Three Tiers at Charmouth in Dorset.

Owing to mishaps during boring operations, the complete sequence of the Lower Lias clays was not displayed in the cores. The beds which were seen, however, yielded the following characteristic fossils :—

Depth in feet.	
531–532	Pentacrinus sp. [columnals]
645	Rhynchonella *cf.* rostellata (*Quenst.*)
647	Astarte sp.
650	Grammatodon intermedius (*Simp.*)
504	Gryphaea *cf.* cymbium (*Lam.*)
552½	Lima pectinoides *J. Sow.*
560, 647	Nuculana sp. (B.)
530, 532, 550	,, sp.
560, 564	,, sp.
552½	Ostrea sp.
532, 563, 650	Pecten (Syncyclonema) liasianus *Nyst*
531, 560, 647	Protocardia sp.
532, 560, 645	Pteria (Oxytoma) sp.
563	Actaeonina *cf.* ilminsterensis *Moore*
550	Chemnitzia sp.
530	Aegoceras *cf.* lataecosta (*J. de C. Sow.*)
647	Tragophylloceras ?

The occurrence of the ammonite which is brought into comparison with *Aegoceras lataecosta* (J. de C. Sow.) proves the presence of the Capricornus Zone. The shell is well preserved, and was found in a thin band of limestone, 2 feet below the top of the sub-division. It is not known at what depth the Jamesoni Beds was entered, owing to the absence of cores, but at 644 feet a dark grey earthy limestone, yielding numerous specimens of *Rhynchonella*, appears to be well within the zone. The shells are identical with the forms brought into comparison with *Rhynchonella rostellata* (Quenst.), found between the depths of 1815 feet and 1818 feet at Brabourne.[2] Like the Kentish

[1] G. W. Lamplugh, F. L. Kitchin, and J. Pringle, ' On the Concealed Mesozoic Rocks in Kent ' (*Mem. Geol. Surv.*), 1923, p. 30.

[2] G. W. Lamplugh and F. L. Kitchin, ' On the Mesozoic Rocks in some of the Coal Explorations in Kent ' (*Mem. Geol. Surv.*), 1911, p. 176.

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specimens, they are smooth until the adult stage is well advanced, when plications are developed. At Severals House the shells occur in some profusion on a level about the depth of 645 feet. *Nuculana sp.* (B) is another species of importance which is also characteristic of the Lower Lias of Brabourne and other borings in Kent, where, as in Norfolk, it ranges from the Jamesoni Beds up to the Capricornus Zone. Its resemblance to *Nuculana quenstedti* (Tate) has already been commented on,[1] but the shell awaits further description.

It is impossible to state how much more of the Lower Lias remained to be bored through before reaching older formations; but comparing the thickness of the Lias with that of the Middle and Upper Jurassic rocks proved in the area, it will be seen that sedimentation was proceeding more rapidly during the accumulation of the Lias than throughout the periods which followed. As already pointed out, so far as the clays of the Lower Lias have been penetrated, they do not indicate the near proximity of a shore-line. It is possible that the Jamesoni Beds may rest unconformably on older rocks in this area, as at Brabourne and Dover in Kent; but further borings alone can settle the question.

APPENDIX II

On the Ammonite Horizons of the Gault and Contiguous Deposits

By L. F. Spath, D.Sc.

By permission of the Director of the Geological Survey the writer was enabled to incorporate in his account of an 'Excursion to Folkestone,'[2] some of the results of an examination of the well-known Gault locality of East Wear Bay, undertaken on behalf of the Survey. In addition to reporting on recent changes in the classical cliff-section, the writer collected numerous fossils, especially from the rather barren upper beds XI–XIII, Mr. S. W. Hester rendering valuable assistance. This allowed of a more detailed subdivision of the upper sixty feet, or more than half the total thickness, of Gault, misleadingly grouped by Price[3] as one 'Zone of *A. rostratus*,' whilst modern French authors[4] still include in this one 'Zone à *Mortoniceras inflatum*' the whole of the Upper Gault. Price had named nine out of his eleven 'zones' after ammonites, but six of these nine zonal ammonites were wrongly identified and Jukes-Browne's later account[5] was equally unsatisfactory. The records of such notorious species as *Hoplites 'interruptus,' raulinianus, auritus*

[1] *Op. cit.*, p. 175.
[2] *Proc. Geol. Assoc.*, vol. xxxiv, 1923, pp. 70–76.
[3] 'The Gault,' 1879, table on p. 12.
[4] See Tomitch, 'Contrib. Connaiss. Étage Albien,' &c. (Notes Provençales du Dr. Guébhard, No. vi, St.-Vallier-de-Thiey). Le Mans, 1918.
[5] 'Cret. Rocks of Britain. I. The Gault and Upper Greensand' (*Mem. Geol. Surv.*), 1900.

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and *denarius* are generally useless on account of the confusion of externally similar forms belonging to different horizons in the Gault. A table prepared by the writer and included in the above Excursion Report gives a new subdivision of the Albian age and a correlation of its zones with the various beds found at Folkestone.

The occurrence of '*Anahoplites*' of the *catillus*-group in the lower part (where *Anisoceras* is particularly common) of bed XI, already recorded by Dr. Kitchin and Mr. Pringle in this Summary[1] was confirmed, also the absence of true *Turrilites*; and of special interest was the recognition of the succession in time of the various dipoloceratid genera, in view of recent criticisms by Stieler.[2] The writer's contention[3] that the genus proposed for the *rostratus*-group may require further subdivision was justified and Stieler's statement[4] that comprehensive interpretation of species is particularly necessary in the case of the *Inflaticerata* can only be ascribed to limited knowledge of the richness and variety of the Gault fauna. It may be useful to state briefly the vertical distribution, as known at present, of the keeled ammonites of the Gault (*Dipoloceratidae*) and of the various Folkestone *Hoplites*, so abundantly represented in all collections.

Eight dipoloceratid genera are known to occur, but two others namely, *Oxytropidoceras* and *Falloticeras*, with the lyelliceratid genera *Brancoceras*, *Tegoceras*, and *Raulinieras*, have not yet been found in this country. The earliest is *Mojsisovicsia* (bed IV) followed by *Dipoloceras* (beds V–VIII). The Upper Gault descendants of the latter appear to have the following ranges :—

Elobiceras	Beds IX & X
Hysteroceras	„ VIII to XI
Prohysteroceras	„ IX to XI
Inflaticeras	„ XI & XII
Neoharpoceras	„ XI & XII
Neokentroceras ?	Bed XIII

The hoplitid genera have been provisionally classed into seven groups, of which only four are at present named. The group of '*Hoplites*' *puzosianus* and '*H.*' *raulinianus* (d'Orbigny) is restricted[5] to bed Ia; *Hoplites* s.s. (*dentatus*-group) to beds I to III. The latter gives rise to two stocks that persist to bed XI, namely *Anahoplites*, Hyatt emend. Spath, comprising the groups of *A. splendens* and *A. tethydis*, connected by innumerable transitions, and the group of '*Hoplites*' *lautus* and '*H.*' *tuberculatus*. The *tethydis*-group leads to *Ammonites denarius* and *A. auritus*,[6] wrongly compared by Kilian and Sinzow to *Saynella* and confined

[1] 'Summary of Progress for 1920' (*Mem. Geol. Surv.*), 1921, p. 62.

[2] 'Anomale Münd. b. Inflaticeraten,' *Neues Jahrb. f. Min.*, etc., Beil., Bd. xlvii, 1922, p. 339. 'Üb. Gault- u. Cenoman-Ammon. a. d. Cenoman d. Cap Blanc Nez,' *Neues Jahrb. für Min.*, etc., 1922, Band ii, Heft 2, p. 34.

[3] 'On Cretaceous Ammonoidea from Angola,' *Trans. Roy. Soc. Edinb.*, vol. liii, pt. 1, No. 6, 1922, p. 97.

[4] *Loc. cit.* (1922, 'Anomale Münd.'), p. 340.

[5] '*Hoplites*' in the Excursion Report, *loc. cit.*, p. 74.

[6] '*Anahoplites*,' *ib.*, p. 76.

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to beds X and XI; the *denarius*-stock again leads to *Pleurohoplites* of bed XIII. The *lautus-tuberculatus*-type is continued in *Hyphoplites* of the *dispar*-zone and the Lower Cenomanian.

Other information not incorporated in the Excursion Report was obtained from some inland sections near Folkestone. In the Broadmead sand-pit at Cheriton the following sequence was shown :—

		Ft.	in.
	Soil	1	0
dentatus-zone	Clayey Greensand with *Hoplites dentatus*, &c.	2	0
	Line of 'Sulphur Nodules' without fossils	0	4
Non-sequence			
mammillatus-zone	Greensand	1	6
	Upper line of nodules with *Dourilleiceras monile* (J. Sow.), *D.* cf. *mammillatum* (Schloth.), *Beudanticeras ligatum* (Newt. and Jukes-Browne) and fossil wood	0	3
	Yellow sand	1	6
	Lower line of iron-stained nodules with *Douvilleiceras monile*, *Beudanticeras ligatum*, *Ostrea sp.*, *Pecten sp.*	0	3
Folkestone Sands	Silver-sand, without fossils	10–12 ft.	

The absence from the Folkestone area of the *regularis*-fauna has already been noticed by Dr. Kitchin in this Summary.[1]

In the shallow Broadmead clay-pit, belonging to the same works (Lord Radnor's), no fresh section was visible, and yellowish clays, yielding (loose) fossils like '*Hoplites*' aff. *proboscideus* (J. Sow.) '*H.*' *lautus* (J. Sow.), and *Anahoplites sp. nov.*, presumably from the top of the Lower Gault, were covered by chalky hill-wash.

Similarly the equally shallow Cheriton Pit, though mostly in lower (blue) Gault clay, did not offer a satisfactory, clean section, but both the yellowish Upper Gault (beds IX, X, and basal XI) and the blue Lower Gault (beds II or III to VIII) were exposed in a very clear 35–40 ft. section in the pit of the Brick and Tile Co. at Elenden Gardens, Cheriton. The beds are not uniform in colour or lithological character across the face of the pit, and at the western end, the top includes a greater portion of bed XI, below a foot or so of surface-soil, than at the eastern end, where the summit is low down in XI. Also, the hard bands in bed IX are very irregular, as seen on the face of the pit; but the 15–18 ft. of Upper Gault, to within a foot of the base of bed IX, is of a very distinctive yellow colour, sharply marked off from about twenty feet of more or less uniform, dark blue, Lower Gault, with irregular patches rather than bands weathering to a lighter blue. The light buff clay of bed III ('crab-bed') that forms a conspicuous, precipitous, seam in the cliff-section at Copt Point, was not distinct at the base of the pit; and the 'mottled bed' (VI) was not clearly recognizable. Conversely at 2, 6, and

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 45.

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10 feet up, nodular bands were seen, but could not be correlated exactly with those, for instance, of bed IV at Copt Point. According to the foreman, the base of the Gault clay was met with 12 ft. below the floor of the pit. Some new species of *Hoplites* and *Anahoplites*, peculiar to beds II and III on the coast, were discovered in the lowest five feet, associated with *Hamites attenuatus* J. Sowerby; but no detailed zonal collecting was done to ascertain the changes in the various beds and their apparent thickening in the short distance from the coast.

It may be useful to discuss the less local aspects of the Albian succession. Collecting in lower beds, and especially in the Gault of Wiltshire and other important areas, has not yet been done with the detail necessary to enable the writer to place, for example, the *Lyelliceras* fauna, absent from Folkestone, and almost certainly fairly low in the Lower Gault. The *benettianus* and *inaequinodus* faunas of Wiltshire and North Dorset are also at present only assumed to have existed during the time-interval that preceded the deposition, on the sandy substratum of the *mammillatus*-zone, of the lowest clay-beds at Folkestone.

The uppermost and lowest beds of the Albian, and the relations of their ammonite-faunas to those of the contiguous formations require special consideration.

A fauna characterized by species of *Stoliczkaia* and by large, inflated forms of *Pleurohoplites* (*dispar*-zone) succeeds an earlier *Pleurohoplites*-fauna with small examples of *Pl. studeri* and the compressed forms of the type of *Pl. renauxianus* (d'Orbigny). The later (= *dispar*) fauna is found in North Dorset ('Upper Greensand') and is included in the phosphate-bed of Cambridge, in which deposit, however, the earlier *Pleurohoplites* and even the *aequatorialis* faunas (of the 'Chert' and 'Malm' Series of the Upper Greensand) are also represented.[1] It is uncertain to which of these three upper Albian zones must be referred the Mediterranean elements of the Cambridge Greensand, namely, *Phylloceras*, *Lytoceras* (*Gaudryceras*), *Tetragonites*, and *Desmoceras* ('*Latidorsella*'). It is also interesting to note that the lytoceratid genus *Kossmatella* has not yet been discovered in this country. It ranges through a number of horizons in Mediterranean deposits, but is referred by Jacob[2] to the '*dentatus*' or even '*tardefurcata*' zones, though other authors have recorded it from the Upper Albian. In the Drôme[3] some of its representatives are associated with *Phylloceras sp.*, *Tetragonites timotheanus*

[1] The forty feet or so of unfossiliferous clays below the phosphate-bed appear to correspond mainly to the *auritus*-zone of Folkestone, and the 'abundance of Lower Gault fossils in the Cambridge Greensand' ('Geology in the Field,' 1909, p. 151) has no real existence.

[2] 'Ammon. Crét. Moyen,' etc., *Mém. Soc. Géol. France, Pal.*, No. 38, 1907, pp. 21–3. W. Kilian ('Crét. Infér. France,' *Mém. Carte Géol. France*, 1920, p. 27) records *Kossmatella chabaudi* (Fallot) from the Lower Albian, as well as '*Gaudryceras sacya* (Stoliczka)' which is almost certainly due to misidentification.

[3] E. Fallot. 'Étude Géol. Étages Moyens & Supér. Terrain Crét. S.E. France,' *Bibl. École Hautes Études, Sect. Sci. Nat.*, xxx, 1, 1885, p. 153.

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(Pictet), and *Desmoceras latidorsatum* (Michelin), three Cambridge Greensand types of little value for exact correlation; but this *Kossmatella*-bed is followed by shales with *Gaudryceras dozei* (Fallot) and undoubted Cenomanian *Turrilites*, probably corresponding to the *martimpreyi* beds of Aumale in Algeria.[1] At Ventnor, where *Pleurohoplites renauxianus* occurs, though *Stoliczkaia* has not yet been found, such supposed Lower Chalk species as *Gaudryceras leptonema* (Sharpe), *Phylloceras* '*velledae*' (Sharpe, *pars*, *non* Michelin, = *Ph. seresitense* Pervinquière) and *Puzosia octosulcata* (Sharpe) have been collected. There is little difference between the chalky matrix of these and that of the Albian *Pleurohoplites*. But Sharpe's *A. leptonema* is unlike any described species of Albian *Gaudryceras*, except possibly a Japanese *Lytoceras sp.* of uncertain horizon, figured by Yokoyama[2] and compared to *Gaudryceras sacya* (Forbes); and a doubtful example of *G. leptonema* from Devon recorded by Jukes-Browne[3] is associated with a true Cenomanian fauna.

Some work, then, remains to be done with regard to the exact horizon of several of these Mediterranean elements; but it may be mentioned that only one Cambridge Greensand ammonite, namely, *Puzosia sp. nov.* = *A. mayorianus* Seeley [*non* d'Orbigny], preserved indifferently in black or brown phosphate, has so far been found also in the Cenomanian (Chloritic Marl) of Warminster and Bonchurch. It will be readily admitted that a long-lived desmoceratid like *Puzosia* has no zonal value.

In the earliest British Cenomanian deposits *Schloenbachia*[4] is associated with *Mantelliceras couloni* (d'Orbigny) and *M. martimpreyi* (Coquand) and allied species and with two new genera, both represented by unnamed Warminster species, namely, *Submantelliceras* gen. nov. (type: *Acanthoceras aumalense* [Coquand] Pervinquière: 'Ammon. Crét. Algér.,' *Mém. Soc. Géol. France, Pal.*, (42), 1910, p. 42, pl. iv, fig. 11) and *Euhystrichoceras* gen. nov. (type: *Mortoniceras? nicaisi* [Coquand] Pervinquière, *ibid.*, p. 65, pl. vi, figs. 18, 19). The zone of *Pecten asper* has, of course, long been found to be valueless, and Barrois's 'Zone of *A.* [*Sharpeiceras*] *laticlavius*,' according to Stieler,[5] at the type locality Cap Blanc Nez contains not only derived Lower and Upper Gault fossils, but *Mantelliceras* and *Calycoceras* from well above the base of the Cenomanian. How the occurrence in this supposed Cenomanian bed of, for instance,

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[1] L. Pervinquière. 'Ammon. Crét. Algér.,' *Mém. Soc. Géol. France, Pal.*, vol. xvii, 1910, Mém. No. 42, p. 77.

[2] 'Verst. Japan. Kreide,' *Palæontogr.*, vol. xxxvi, 1890, p. 180, pl. xix, figs. 3a, b.

[3] In Jukes-Browne and Hill. *Quart. Journ. Geol. Soc.*, vol. lii, 1896, p. 163.

[4] Stieler's (*loc. cit.*, 1922, 'Blanc Nez,' p. 30) identification of *Schloenbachia intermedia* (Mantell) with *S. costata* (Sharpe) seems to show that some of the numerous British species of *Schloenbachia* are unknown on the Continent.

[5] *Ibid.*, pp. 25–26.

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a derived *Douvilleiceras mammillatum* can be reconciled with Stieler's[1] statement that at Cap Blanc Nez, the Gault 'in its complete development' is overlain conformably by the Cenomanian, the writer is at a loss to understand. So far as observations go the Cenomanian seems to be divisible into the following ammonite-horizons :—

Upper Cenomanian	Metoicoceras pontieri
(Acanthoceratan)	Acanthoceras cenomanense
[*subglobosus*-zone of authors]	Calycoceras baylei
Lower Cenomanian	Euomphaloceras euomphalum[2]
(Schloenbachian)	Hyphoplites falcatus
[*varians*-zone of authors]	Mantelliceras martimpreyi

Better species may be found for these horizons when the necessary field-work has been done, and the lower three especially, forming the *varians*-zone of most authors, should yield distinctive species of the common genus *Schloenbachia*. The tuberculate early forms of *Calycoceras* of the *falcatus*-zone lead to two developments that flourished before the costate *Calycoceras* (*baylei*-group) and *Acanthoceras* s.s. became dominant. One (*Eucalycoceras* gen. nov.) includes '*Acanthoceras*' *newboldi* Kossmat and its var. *spinosa*, better renamed *Eucalycoceras spinosum*, '*Ac.*' *choffati* and '*Ac.*' *gothicum* Kossmat and others, and as type may be taken *Eucalycoceras pentagonum* Jukes-Browne (*Quart. Journ. Geol. Soc.*, vol. lii, 1896, pl. v, figs. 1, 1a). The other stock (*Protacanthoceras* gen. nov.) via *P. triserialis* (J. de C. Sow.) leads to *P. compressum* (Jukes-Browne) and *P. bunburianum* (Sharpe) (genotype, *loc. cit.*, 1854, p. 25, pl. ix, figs. 3a–c), and several unnamed forms. *P. hippocastanum* (J. de C. Sow.) is transitional from this to the typical, later, *Acanthoceras*, occurring chiefly in the *baylei*-zone, with flattened forms of the type of *Ac. vicinale* (Stoliczka) in the next higher zone. It may be added that *A. rhotomagense* (Defrance MS.)[3] is the genotype of *Acanthoceras* and Hyatt's *Metacanthoplites* must be rejected; whilst for *A. deverianus* d'Orbigny ('Pal. Franç., Terr. Crét.,' i, 1841, p. 356, pl. cx), generally erroneously included in *Acanthoceras*, the new genus *Romaniceras* is proposed; and for *A. peltoceroides* Pavlow ('Argiles de Speeton,' 1892, p. 152, pl. xviii, fig. 21), also wrongly referred to *Acanthoceras*, the new genus *Parastieria*.

Now the interesting problem arises whether faunas with ammonites such as *Hypengonoceras warthi* in India or *Knemiceras*

[1] *Ibid.*, p. 22.

[2] The new genus *Euomphaloceras* (type: *A. euomphalus*—Sharpe, 'Foss. Moll. Chalk,' pt. 2, 1854, p. 31, pl. xiii, fig. 4, *Palæontographical Society*; Brit. Mus., No. 50158) is here proposed for this stock, which has nothing to do with *Douvilleiceras*. Its suture-line resembles that of *Acanthoceras sussexense* and *A. cunningtoni*. (*See* Spath: 'Cret. Cephalop. from Zululand,' *Annals South African Mus.*, vol. xii, pt. vii, No. 16, 1921, p. 314.

[3] In Brongniart: 'Descr. Géol. des Environs de Paris,' 1822, p. 83, pl. iv, fig. 2. Sowerby's *A. rhotomagensis* ('Mineral Conchol.', 1826, vol. vi, p. 25, pl. 515, fig. 1, B.M. No. 43983a) is specifically distinct and may be renamed *Acanthoceras subflexuosum* sp. nov. The original of fig. 2 agrees with Mantell's *A. sussexensis*.

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uhligi in Portugal represent southern equivalents of our Upper Albian or Lower Cenomanian, or whether they existed during a time interval in which no deposits were laid down in north-western Europe. *Knemiceras uhligi*, of course, has been erroneously recorded from Lower Albian as well as Cenomanian strata; but in Portugal,[1] in the lower Bellasian zone I, it is associated with '*Schloenbachia inflata*, var. *lampasensis*' Choffat, which, though of somewhat unusual appearance, is probably related to some of the quadrituberculate species of *Inflaticeras* described by the writer from Angola.[2] In Tunis, *Knemiceras uhligi* occurs in beds classed by Pervinquière as Vraconnian, but including not only several horizons of the Upper Albian, but also undoubted Cenomanian fossils, *e.g.*, *Forbesiceras obtectum* (Sharpe) of the *falcatus*-zone.

In India, *Stoliczkaia* of the uppermost Albian and Lower Cenomanian is found, as well as *Mantelliceras*, *Sharpeiceras*, and *Forbesiceras*. It is thus fair to assume that dissimilar faunas here do not indicate deposits of different ages, even if detailed collecting in new areas may enable us to increase considerably the number of hemeræ here recognised. It is possible that the *euomphalus* and *falcatus* zones, on further research, may be found to be divisible into such a sequence as the following :—

- Protacanthoceras compressum (*Jukes-Browne*)
- Schloenbachia costata (*Sharpe*)
- Forbesiceras sp. [aff. *complanatum* Mantell]
- Calycoceras naviculare (*Sharpe*) [*non* Mantell]
- Mantelliceras sp. [aff. *feraudianum* Sharpe, *non* d'Orb.]
- Mantelliceras mantelli (*J. Sow.*)

But in India other forms would represent the same succession and at Aumale in Algeria neither the English nor the Indian zonal species may be traceable though the same horizons are clearly developed. Local non-sequences may have no relation to the absence of whole faunas. That in southern deposits just those horizons or ages[3] are missing that were preserved in north-western Europe, and vice versâ, is as little probable as that ammonites had a uniform world-wide distribution. *Hypengonoceras*, like the earlier *Engonoceras* and other Pseudoceratites, or like the persistent radical stocks *Phylloceratidae* and *Lytoceratidae* in general, did not penetrate into the areas of temporary transgressions, where the rapidly modifying derivatives of these two 'stenothermal' families enormously increase. The genus *Oxytropidoceras* (*roissyanus*-group), referred to above, is common in North-, Central-, and South-America, in addition to Mediterranean countries, and in South Africa it is associated with Dipoloceratids of the upper part of the Lower Gault. But Hoplitids which in Western Europe far outnumber *e.g.* *Oxytropidoceras* or *Lyelliceras*, are absent in these American and African deposits.

[1] P. Choffat. 'Faune Crét. Portug.,' I, 1886, p. 47. *Comm. Trav. géol. Portugal.*

[2] *Loc. cit.* (Angola, 1922), pp. 115–18.

[3] S. S. Buckman, 'Type Ammonites,' pt. xxxiv, 1922, p. 7.

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Mr. Buckman's[1] comparison, say, of the *transversarius*-fauna of Mediterranean countries with the *martelli*-fauna of England, without consideration of the ever-present *Sowerbyceras* and '*Haploceras*' on the one hand, and Cardioceratids on the other, that clearly demonstrate the limited horizontal distribution of certain ammonites, is undoubtedly open to criticism.

As regards the lower limit of the Albian, Ganz,[2] in 1912, placed the '*nodosocostatum*-zone' again in the Gargasian or Upper Aptian, but Kilian[3] in 1913, showed that Jacob and Stolley had been right in including the *nodosocostatum*-zone, or Clansayes horizon, in the Albian, and this classification is here adopted. Incidentally it may be remarked that Ganz also reviewed the history of the term Gault, as Jacob[4] had done in 1908, unfortunately equally unsuccessfully on account of incomplete knowledge of the English type-succession. It may suffice to point in this connexion to the curious mixture of Upper and Lower Gault forms that he records from his 'Lochwald Bed' (p. 121) or to the supposed occurrence in the Cenomanian of *Hysteroceras varicosum* (p. 129).

Of the lowest six subzones of the Albian, namely :—

tardefurcata-zone	*regularis* subzone
	milletianus ,,
	schrammeni ,,
nodosocostatum-zone	*jacobi* ,,
	trautscholdi ,,
	abichi ,,

none has been identified in the Folkestone Sands. Mr. W. J. Atkinson, of Hythe, to whom the writer is indebted for much information regarding local beds of the Lower Greensand, sent a photograph of what appears to be a large *Parahoplites* of Upper Aptian age, said to come from the uppermost part of the Folkestone Sands at Sandling Junction. On the other hand, *Parahoplites* (*Acanthoplites*?) *simmsi* (Forbes) from Hythe, greatly resembling *Acanthoplites aschiltaensis* (Anthula), is preserved in an ironstone that cannot be higher than the base of the Folkestone Sands, where Topley noticed a brown ferruginous sandstone with nodules in which Price[5] found 'two ammonites.' Again, Meyer[6] regarded the Nutfield Beds [with Upper Aptian *Parahoplites* and

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[1] 'Type Ammonites,' part xxxvii, 1922, p. 25.

[2] 'Stratigr. Mittl. Kreide, Ob. Helvet. Decken, N. Schweiz. Alp.,' *Neue Denkschr. Schweiz. Naturf. Gesellsch.*, vol. xlvii, 1912, p. 144.

[3] In Frech. 'Lethæa Geogn.,' vol. ii, Mesozoic., pt. iii, Kreide, i, Unterkreide, fasc. 3, 1913, p. 347.

[4] 'Études Pal. & Strat. sur la Partie Moy. d. Ter. Crét.,' *Trav. Lab. Géol. Univ. Grenoble*, vol. viii, 1908, p. 584.

[5] 'Excursion to Hythe, Sandgate and Folkestone,' pt. ii, *Proc. Geol. Assoc.*, vol. xiii, 1893, p. 148.

[6] 'Notes on the Correlation of the Cretaceous Rocks of the S.E. and W. of England,' *Geol. Mag.*, 1866, p. 15.

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Ammonitoceras] as being near the base of the Folkestone Sands and at about the same horizon as the Bargate Stone. The ammonite-fauna of the Bargate Stone, including true *Parahoplites* of the *nutfieldensis*-group, fully confirms Meyer's correlation, and the Folkestone Sands (beds I–III of Price) may thus correspond to the uppermost Aptian as correlated by Prof. Gregory,[1] or to the Lower Albian as indicated in the writer's table; or, what is more probable, with their nodule-beds above and below and possible non-sequences in between, the Folkestone Sands may represent the vestiges of a complicated succession of geological events that took place between the deposition of the *nutfieldensis*-beds from Kent to Wiltshire on the one hand and the existence of the *regularis*-fauna of Bedfordshire on the other. No ammonites seem to be known from the Sandgate Beds apart from the fragment recorded by Dr. Kitchin[2]; but in the Kentish Rag Beds of Hythe there are already Lower Aptian ammonites, including *Parahoplitoides*, *Dufrenoyia*,[3] *Cheloniceras* and '*Ancycloceras*.'

A provisional table of the ammonite zones of the Aptian may here be inserted. It is based on the attempts at correlation published by the writer[4] on previous occasions; but the '*furcatus*-zone,' formerly adopted with considerable doubt from French authors, notably Kilian[5] and Jacob,[6] has been omitted since the identification of *A. furcatus* Sowerby with the Lower Gargasian *Dufrenoyia dufrenoyi* (d'Orbigny) is obviously wrong. Jukes-Browne's term 'Vectian,' like his 'Selbornian,' is unnecessary.

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[1] 'On a Collection of Fossils from the Lower Greensand of Great Chart, in Kent,' *Geol. Mag.*, 1895, p. 103.

[2] In Lamplugh and Kitchin, 'On the Mesozoic Rocks in some of the Coal Explor. in Kent' (*Mem. Geol. Surv.*), 1911, p. 144.

[3] The genus *Dufrenoyia* Burckhardt, quoted by Kilian in 1915 ('La Faune de l'Aptien Infér. d. Environs de Montélimar,' Contr. à l'Étude d. Faunes Paléocrét. du S.E. de la France. I. *Mém. Carte Géol. France*, pp. 34, 35, 37; spelt '*Dufrenoya*' on pp. 178, 196, 198, 199, 203, 205, 207), has priority before *Stenhoplites* Spath ('On Cret. Ammonoidea from Angola,' *Trans. Roy. Soc. Edinb.*, vol. liii, pt. i, No. 6, 1922, p. 110); but according to kind information by Prof. Kilian, the name *Dufrenoyia* has not been published by Burckhardt. It may be advisable to retain the genus *Stenhoplites* for *A. furcatus* Sowerby, quite distinct from *D. dufrenoyi* (d'Orbigny) and of pre-*deshayesi* age. The genus *Hoplitides* v. Koenen, used by Franke ('Die Entfaltung d. Hopliten i. d. Unt. Kreide Nord-deutschl.,' *Jahrb. k. preuss. geol. Landesanst.*, vol. xxxix, Teil I, Heft 3 (1918), 1920, pp. 491–3) for the group of '*Parahoplites*' *deshayesi* (Leymerie) has been restricted by Sayn ('Les Ammon. pyrit. d. Marnes Valangin. d. S.E. de la France,' *Mém. Soc. Géol. France, Pal.*, vol. xv, fasc. 2, No. 23, 1907, p. 64) to a division of *Leopoldia* occurring in the Valanginian Bed D2 at Speeton.

[4] *See* 'On Cret. Cephalopoda from Zululand,' *Ann. South Afr. Mus.*, vol. xii, pt. vii, No. 16, 1921, p. 311.

[5] 'La Faune de l'Aptien Infér. d. Environs de Montélimar,' Contr. à l'Étude d. Faunes Paléocrét. du S.E. de la France. I. *Mém. Carte Géol. France*, 1915, table to p. 114.

[6] 'Études Paléont. et Strat. sur la Partie Moy. des Terr. Crét.,' etc., *Trav. Lab. Géol. Univers. Grenoble*, vol. viii, 1908, p. 587.

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Ammonite Zones of the Aptian.

	Zones.	Subzones.	
Upper Aptian (Gargasian)	*subnodosocostatum*-zone (Parahoplitan)	aschiltaensis	Folkestone Sands? / I. o. W. Sandrock Ser.
		nutfieldensis	Nutfield; Seend; Pulborough; Shanklin; Bargate Stone.
	martini-zone (Tropæuman)	tovilense	Maidstone
		bowerbanki	I.o.Wight,Ferrug. Sands
		hillsi	Hythe Rag; Upware
Lower Aptian (Bedoulian)	*deshayesi*-zone (Parahoplitoidan)	consobrinoides	I.o.Wight Crackers
		hambrovi	
		weissi	Atherfield Clay
		bodei	Perna Bed; Hunstanton Carstone; Speeton, B, top
	(Parancyloceratan)	bidentatus	Speeton, B., top
		rude	
		sparsicosta	

It is inadvisable to use terms like ' Sandgate Beds ' or 'Atherfield Clay ' for wider correlations ; for even in such closely neighbouring localities as Dover, Hythe, and Brabourne the sandy, glauconitic, or clayey beds respectively do not belong to the same palæontological horizons.

Much work, of course, remains to be done on the Lower Greensand faunas. Hitherto the tendency has been to rely too much on the relative position of beds to relegate them to some formation intermediate between the over- and under-lying strata, sometimes in contradiction to fossil-evidence and with the sole desire of making the sequence complete. The ' Punfield Beds,' for example, styled Neocomian by Price,[1] were promptly taken by Kayser[2] to cover the two enormously long periods of the Valanginian and Hauterivian, and in his table are followed by the ' Atherfield Beds,' according to this author of Barremian age, and said to contain *Simbirskites decheni*. In reality none of these formations are represented in the marine Lower Cretaceous of the South of England and even the lowest Aptian is missing. The only ammonite of the Ferruginous Sands in the Punfield Series is a *Parahoplitoides*, transitional to *Dufrenoyia*, and probably younger, not older, than the *Parahoplitoides* of the Atherfield Clay, itself well above the base of the Aptian.

[1] ' The Gault,' 1879, p. 8.

[2] ' Lehrb. d. Geol.,' 3. Aufl., II. Theil. Geol. Formationskunde, 1908, table on p. 483.

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Again, Bed B of the Speeton Clay, the so-called *brunsvicensis*-zone, has *Simbirskites* of the group of *S. discofalcatus* (Lahusen) and *S. carinatus* (v. Koenen) at the base, and Aptian *Parahoplitoides* of the *bodei*-subzone (horizon of the base of the Hunstanton Carstone) at the top. Not a single typical Barremian ammonite has been found in the intermediate beds, though Barremian *Acrioceras* of the group of *A. tabarellii* (Astier) and *A. silesiacum* (Uhlig), here recorded for the first time, occur in the Snettisham Clay. Even in Germany the '*Crioceras*' of the beds between the Hauterivian below and the Aptian above show merely resemblance to, but not identity with, the forms of the typical Barremian, and the less complete succession at Speeton probably includes only part of the Barremian formation. The gap between the Aptian and Albian beds, however, at Speeton is far greater than that between the Lower Albian *regularis*-horizon of Leighton Buzzard and the Upper Aptian *nutfieldensis*-subzone of Surrey, Sussex, Kent, Wiltshire, and the Isle of Wight.

The great confusion existing at the present day in correlations of the Albian has been due largely to the reference to the 'Gault' of beds characterized by faunas of various ages; for instance, the *Parahoplites*-faunas of *nutfieldensis*-age in Mangyschlak and the Caucasus, the Upper Aptian beds of the Luitere Zug[1] with *Diadochoceras subnodosocostatum* (Sinzow), the Aptian faunas of North Germany, or the Lower Horsetown Beds of California, etc. It is to be hoped that the forthcoming description by the writer of the ammonites of the English Gault may help to clear up any doubts remaining about the exact horizons represented in the type-succession; and may cause to disappear from our fossil lists of the Gault such species as the Cenomanian *Protacanthoceras triserialis* (J. de C. Sow.), the Aptian '*Ammonites*' *bicurvatus* Michelin and *Parahoplitoides deshayesi* (Leymerie), the Valanginian '*A.*' *carteroni* d'Orbigny, and the Lower Liassic *Polymorphites parvus* (J. de C. Sowerby).

[1] Jacob & Tobler. 'Gault de la Vallée de la Engelberger Aa,' *Mém. Soc. Pal. Suisse*, vol. xxxiii, 1906, pp. 1–26, pls. i, ii.

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TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS. In accordance with our terms of reference we, the Geological Survey Board, beg to submit our Fourth Annual Report on the work of the Survey and Museum.

1. In our previous Reports (1921 and 1922) we dealt with the extended scope of the work of the Survey and with the objects this work had in view. We noted that the increase in staff necessary for the performance of these functions had been authorised and that successive additions had accordingly been made. We are now in a position to report with satisfaction that the establishment has been completed and that despite the large proportion of officers whose experience of work in the Survey is as yet but short it has been found possible to embark on the full programme of work including the revision of the Yorkshire and Fifeshire Coalfields. The record of the Survey for 1923 is one of marked progress and we would draw special attention to the large number of memoirs and maps published during the year.

2. Nine Field Units have been engaged on surveys of the Districts prescribed by the programme approved for the year, viz. :—

(*a*) London and South Eastern District (primary six-inch survey).

(*b*) Midland District with North Wales (primary six-inch survey).

(*c*) South West Highland District (primary six-inch survey) and Ayrshire Coalfield (revision).

(*d*) North Highland District (primary six-inch survey) and Central Coalfield of Scotland (revision).

(*e*) Northumberland and Durham District
(*f*) Cumberland District
(*g*) Lancashire District
} (re-surveys commenced in 1921).

(*h*) Yorkshire Coalfield
(*i*) Fifeshire Coalfield
} (revision commenced in 1923).

The Director's Report gives particulars of the work carried out in each of these areas in the course of the year. The progress recorded is entirely satisfactory both in respect of the extent of ground mapped and of the skill with which the geology of the several districts is being interpreted.

On a review of the work to be taken up by the Survey in the near future we found it necessary to make representation to your Lordships on the urgency of the need for the rapid revision of

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the survey of the Ayrshire Coalfield and of the Central Coalfield of Scotland. We then recommended that the primary six-inch survey of the Highlands should be suspended in 1924 to allow of acceleration of work in these coalfields, and that the resumption of work on the primary survey should be reconsidered at the end of 1924 in the light of the progress made in the coalfield revision. Your Lordships approved this recommendation, which necessitated some modifications in the work allocated for 1923; details of these modifications are given in the Director's Report. In view of the resulting delay of work in the Highlands, it is gratifying to record that the survey of Mull has been completed. That area is a volcanic centre of extreme complication, and the publication of the full details now available should prove of wide scientific interest.

In each of the two coalfield areas in which revision was commenced in 1923—Yorkshire and Fife—a good beginning has been made in the first season and we are pleased to be able to report that, as in other districts, helpful co-operation is being given by those engaged in the mining industry in the areas.

In Yorkshire the revision was started in the west part of the area so that the work might be connected satisfactorily with that of the unit which is at work in Lancashire. In view of the increasing importance of the Concealed Coalfield of East Yorkshire and Nottinghamshire arrangements have been made for the issue of a new edition of the special memoir on that area which will embody the additional information obtained in the course of the development of the coalfield.

In the Fifeshire Coalfield work was commenced in West Fife to join with the Clackmannan Coalfield to the west, the revision of which has been completed. The year's field work has led to the exact correlation of several of the carboniferous limestone zones in Fife and in the Central Coalfield; this marks an important advance.

3. Several important memoirs are now out of print. It is, however, undesirable to issue new editions without such revision as is necessary to bring the information up to date and, just at present, the urgency of other work makes it difficult to spare experienced geologists for this purpose. Accordingly only those memoirs for which there is most demand have been put in hand for revision and re-issue.

4. We have already referred to the large number of maps issued during the year. We wish to emphasise also that improvements have at the same time been effected in the expression of geology on these maps. All maps are now printed by a six-colour process hitherto in use only for Scottish maps. The (Sheet 31 solid) map of the Central Coalfield of Scotland and the Mull map, with all its complexity, are fine examples of colour printing, and we feel that all concerned are to be congratulated on the excellent technique attained.

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5. The work of various Departments at the Headquarters Office has proceeded along normal lines. The Officers of the Petrographical, Palæontological and Chemical Departments have co-operated with the field staff in the preparation of the memoirs. They have also dealt with current enquiries from Government Departments, Public Services, Institutions and individuals generally.

6. The collection of information relating to metalliferous deposits and economic minerals in Great Britain has been maintained. As detailed in the Director's Report, five volumes have been added to the series of Special Reports dealing with the mineral resources of Great Britain, and other volumes are in preparation.

7. We referred last year to the advantage taken by the Survey of the professional assistance of geologists outside the Survey who had special knowledge and experience of certain sections of the work. This policy has been continued, more particularly in connexion with revision of selected districts in the South of England and with the preparation of water-supply memoirs. The collection of current records as to borings for water and on other matters bearing on water supply has been proceeding systematically and has been greatly forwarded by contributions from engineers, water authorities and others. Memoirs on the Water Supply of Wiltshire and Dorset by Mr. Whitaker and of Gloucestershire by Mr. L. Richardson have been completed and are deposited at the Office in Jermyn Street. These are voluminous documents and if they were printed at this time the cost of issue would be unduly high; publication of the memoirs has therefore been deferred, but the information in these manuscripts as well as all detached but classified records bearing on water supply are held available for reference by enquirers at the headquarter offices of the Survey.

8. We feel that an account, however brief, of the work of the Survey and Museum during the year would be incomplete without special reference to the publication of Dr. Kidston's monumental work on the fossil plants of the Carboniferous Rocks of Great Britain. This work fills a marked gap in palæobotanical literature. Four parts of the monograph were issued in the course of the year, each containing a large number of excellent collotype reproductions.

9. The Ordnance Survey have intimated that for those Counties where the topographical survey has recently been revised, the six-inch topographical maps will be issued in full sheets only. For some parts of these areas the smaller quarter sheets are required for published geological maps, and arrangements have accordingly been made that for such sections, the Geological maps on the six-inch scale will continue to be prepared in quarter-sheets, the revised topography being made available, where necessary, as the printed basis of the geological maps. The extra cost involved

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by the printing of revised topography on the geological maps in quarter-sheet form will be met from funds provided by the Geological Survey.

10. In April, 1923, it became manifest that the roof of the Museum building in Jermyn Street called for repair and the Museum had to be closed to the public. Moreover, at a later date it became necessary to debar inquirers from access to the Survey Offices and the Museum Library and Map-room. In the meantime we had recommended to your Lordships that, in view of the unsatisfactory condition of the Museum building and the lack of adequate accommodation for the staff, steps should be taken to put into effect the recommendation of the Departmental Committee on the Science Museum and Geological Museum in 1912 for the transfer of the Geological Museum to a new building on the site allocated at South Kensington.

We understand that after careful consideration of the position the Government decided, subsequently to the close of the year under review, to erect a new Museum and Offices for the Geological Survey at South Kensington on the site recommended by the Departmental Committee. Meanwhile an entrance to the Survey Offices and Museum Library and Map-room from the Piccadilly front of the Jermyn Street building has been provided, thus restoring facilities for public consultation of the maps and other records of the Survey.

11. The important additions which have been made during the year to the collections of the Museum of Practical Geology and to the Library are detailed in the Director's Report, which also describes the re-arrangement effected to relieve the congestion in the Library.

12. Under the arrangements governing the retirement of members of the Board of Management, three of our colleagues retired at the end of the year under review—Dr. Horne, Professor Marr and Mr. Russell. We desire to place on record our regret at losing their help in our work and our sense of the great value of the special services they have rendered as members of the Board during the initial period of its existence.

13. The Programme of Field Work for 1924 is :—

(1) Continuation of Six-inch original survey in London district and the Midlands.

(2) Revision of Six-inch original survey in Northumberland and Durham, Cumberland, Lancashire, Yorkshire, Ayrshire, Lanarkshire, etc., and Fifeshire (with Kinross).

(3) Continuation of investigation of mineral resources and underground water supplies ; collection of bore records and examination of specimens from borings as occasion arises.

F. G. OGILVIE,
Chairman.

10 *July*, 1924

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REPORT OF THE DIRECTOR OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1923

THERE have been a few additions to the staff of the Geological Survey and Museum during 1923. These were in all cases the appointment of officers to fill vacancies, and the result has been that at the end of the year the establishment is complete for the first time since the commencement of the war in 1914. In August Mr. W. N. Edwards (B.A., Cantab.), and in September Mr. J. Knox (B.Sc., Edinburgh) and Mr. R. C. B. Jones, M.C. (M.Sc., Manchester), were appointed as Geologists on probation. Permanent appointment takes place after two years' satisfactory probation. Mr. Knox was assigned to the Fifeshire unit of the Scottish staff; Mr. Edwards to Yorkshire and Mr. Jones to Lancashire. They were all engaged in field work till the close of the field season. In Scotland an unestablished draughtsman has been added to the drawing staff, and two general assistants have been recruited, one for England and one for Scotland.

In the spring, field work was begun in the revision of the Yorkshire and Fifeshire coalfields. Mr. Bromehead has charge of the work in Yorkshire, but as yet no district office has been opened there and the Yorkshire staff has been centred on London. Four geologists were assigned to this unit, Mr. G. V. Wilson, Mr. D. A. Wray, Mr. J. V. Stephens and Mr. W. N. Edwards. It seemed convenient that a start should be made in West Yorkshire, as in this way contact could be maintained with the unit working in North Lancashire, and uniformity in classification, nomenclature and cartography might be established at the earliest possible date. Mr. Wray, in fact, merely continued his field work of the two previous seasons by crossing the boundary between Sheet 76 (Rochdale, Lancashire) and Sheet 77 (Huddersfield, Yorkshire). The difficulties of correlation and continuity of lines were thus reduced to a minimum. The Yorkshire unit has made a satisfactory beginning, but the senior members have had to devote part of their time to clearing up and finishing the work in which they had been employed before the transfer.

At the same time it became urgent to direct attention to the geology of the very important coalfield of East Yorkshire and Nottinghamshire, which is known as the Concealed Coalfield because the Carboniferous is in large measure overlain by Permian and Triassic rocks. This coalfield has a great future and is undergoing rapid development. In 1913 a special memoir on its geology, by Dr. Walcot Gibson, was published and this is now sold out; before a new edition could be printed a thorough revision was essential. Mr. G. V. Wilson was detailed for this work and has placed himself in communication with the mine managers, mineral borers, etc. of

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that field. Full access has most kindly been given to the geological information by all parties concerned and considerable progress has been made in the work of correlating the sections and bores and in preparing a new edition of the memoir. Towards the close of the year the drawings were being prepared to serve as illustrations of the book.

The revision of the Fifeshire coalfield was also put in hand under Mr. C. H. Dinham as District Geologist, with Mr. D. Haldane, Mr. J. K. Allan and (towards the close of the season) Mr. John Knox as geologists. Work has been carried on in three districts in Sheet 40, viz., Saline, Dunfermline and Lochgelly, all of importance as mining fields. Much gratifying co-operation has been afforded by the mining industry, and, as the structure of this field is very involved, the underground information is essential for a correct reading of the geology. As the ground to the west, in the Alloa and Clackmannan field, has now been almost completely resurveyed it seemed advisable to start in West Fife and proceed eastwards. This step has been justified by the almost complete elucidation of the sequence in the Carboniferous Limestone, which can now be exactly correlated with beds of similar age around the Central Coalfield of Scotland in a manner which has hitherto proved impossible.

The Survey has continued to avail itself of the services of Mr. Osborne White, who for several years has prepared memoirs on selected districts of the South of England. During 1923 he has been engaged in a descriptive account of the geology of the Marlborough Sheet (266), which is nearly ready for the printer. A new colour-printed edition of the map has also been put in hand and a limited amount of revision of drift and solid lines was done by Messrs. Edmunds, Edwards and Dines under the superintendence of Mr. H. Dewey. This map and memoir will be sent to press in 1924.

The memoir on the Geology of the Country around Oxford which was published in 1908 is now out of print and a new edition is in preparation. As this is a district of Mesozoic rocks involving accurate palaeontological investigation, Dr. Kitchin recommended that the information should be as far as possible brought up to date. Arrangements have accordingly been made with Mr. C. J. Bayzand, of the Museum at Oxford, to supply lists of local fossils contained in the collections there and particulars regarding the more important fossil localities from which further collecting is advisable. The work is now in hand and it is hoped that when the new and revised edition is issued it will be of use not only to the general public but also to students specially interested in recent zonal work among the Jurassic and Cretaceous rocks.

Several other important memoirs are out of print and new editions are demanded. In the present state of the Survey staff, however, with so many young geologists requiring training and careful supervision, it is not easy to set free the more experienced

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geologists for work of this description. A second edition of the Glasgow memoir is being prepared by Mr. Murray Macgregor and will be published as early as possible. The Cardiff, Ammanford and Swansea memoirs are all sold out, but it has not yet proved possible to undertake the revision which is necessary to bring the information up to date. The Economic Geology of the Central Coalfield of Scotland, Area V. (Glasgow East, Chryston, Glenboig and Airdrie) is also out of print and a new edition revised by Mr. Murray Macgregor will soon be in the hands of the printer.

In the other districts field work has been carried on in continuation of the field work of 1922. The re-arrangements of staff have been unimportant and though work was delayed towards the close of the season by persistent wet weather the progress has been satisfactory and the general programme has been well carried out.

In the London and South-Eastern District, Mr. Dewey and his staff have completed the six-inch survey of the Romford Sheet (257). This finishes the revision of London and its environs. One London map and memoir (Aylesbury, Sheet 238) have been published during the year and four are in course of preparation or in the press, viz., Dartford (271), Hertford (239), North London (256) and Romford (257), and it is expected that the results of the resurvey will be published at an early date. Instead of continuing eastwards into Essex, it has been decided during 1924 to revise the Aldershot Sheet (285) as that is one which for many reasons has strong claims for attention. The new roads which are being made around London have afforded a number of new sections of the strata, which have been visited and carefully recorded. The district around London is one in which boring for water is constantly going on and a large number of bore records have been received and where advisable the cores have been inspected and searched for fossils.

In the Midland District under Mr. Cantrill surveying was continued in the Wolverhampton Sheet (153), which is now nearly completed, but much information regarding the coalfield has to be collected and reduced to a state suitable for the map and memoir. The Birmingham Sheet (168) is being engraved and the memoir is being written. The Wem Sheet (138), which also was completed in 1922, is being colour-printed. During 1923 the Liverpool memoir and the corresponding map (Sheet 96) were published and a special display of the map, memoir and six-inch standards of that district was made during the meeting of the British Association in Liverpool. A series of geological photographs of the Liverpool district was also shown. The arrangements were in the hands of the Liverpool Geological Society and were excellently carried out.

The North Wales coalfield, of which the revision was completed before the war, was also assigned to Mr. Cantrill when the reorganisation of districts came into force. Progress is being made with the publication of the maps and memoirs, though the work is

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rendered more difficult by the fact that several of the officers who mapped that field have left the Survey for other appointments or have been transferred to other districts. The Flint Sheet (108), in solid and drift editions, is now being colour-printed and the memoir is in page proof. All the six-inch maps of that Sheet which contain Coal Measures are now published. The next Sheet to the south is Wrexham (121) and the six-inch coalfield sheets of that area are being dry-proofed. The memoir and one-inch Sheet are in preparation but not yet ready for press. The Oswestry Sheet (137) will then be taken up, but the maps and the notes for the memoir on that Sheet require careful editing before they are finished.

In Lancashire Mr. W. B. Wright and his staff have practically completed the six-inch revision of the Rochdale Sheet (76). The six-inch maps are now being reduced to standard form and will soon be ready for engraving. The one-inch map and memoir will then be put in hand. This area has proved of great interest as containing a typical and full development of the Millstone Grit, and it has received very careful investigation especially from the point of view of modern zonal stratigraphy in the Carboniferous. The marine bands characterised by goniatites and other fossils have been elaborately mapped and by means of their fauna it has been found possible to divide the sequence into recognisable zones which can be traced over a wide extent of country. This work will have important bearings on the stratigraphy of the adjacent districts of Yorkshire and perhaps other parts of Great Britain where the Millstone Grit occurs. In North Lancashire it has been useful not only in establishing correlations between the grits and shales in different parts of the Sheet but also in proving considerable variations in thickness in the respective members of the sequence which might not otherwise have been clearly ascertained. It has been decided that the Lancashire unit will continue mapping southwards in 1924 within the Manchester Sheet (85), in which the Coal Measures and New Red rocks present problems of considerable difficulty.

Mr. Bernard Smith and his staff in Cumberland in 1922 completed the mapping of the Carlisle (17), Longtown (11) and Silloth (16) Sheets, and the six-inch maps, which will not be published, are being copied in standard form for reference purposes. The three one-inch maps are being engraved and will be published in 1924 and the memoirs descriptive of these Sheets are being compiled. Work was transferred to the Brampton (18) and Shopford (12) Sheets, and satisfactory progress was made. At the same time the mapping of the Whitehaven coalfield (Sheet 28), which has now been in hand for three seasons, was continued. This coalfield has proved very difficult to interpret, as was anticipated when the revision was begun. The sequence was not thoroughly understood and there is much complicated faulting. A satisfactory reading of the sequence has now been attained which solves many

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problems hitherto obscure, and the general structure is clearly understood, though local difficulties remain. The dry-proofing of the coalfield six-inch sheets has been carried on where the survey was finished. Several of these sheets are in progress of engraving. The one-inch map cannot be taken in hand till the six-inch revision is done, but it is hoped that the field season of 1924 will see this work completed. The mass of mining information to be collected and reduced in this district is very heavy, but the mining companies concerned have given full access to all their records.

In the limestones around the coalfield there are important deposits of iron ore which have been extensively worked and are still productive. In 1919 a Special Report on the hæmatite ores of the Cumberland district by Mr. Bernard Smith was published; it has already sold out and a new edition is called for. During the past season Mr. Smith has devoted such time as he could spare from his other duties to a complete revision of this subject. He has been able to add considerably to the facts contained in the memoir and has nearly finished the manuscript for a second edition, which will soon be sent to the press. Explorations for hæmatite deposits are constantly going on, and by keeping in touch with the engineers engaged in the search it is possible to secure much information that would otherwise become lost.

In Northumberland and Durham the revision on the six-inch scale has made rapid progress under Mr. R. G. Carruthers. The three one-inch Sheets of which the survey was finished in 1922, Berwick (Sheet 2), Holy Island (Sheet 4) and Norham (Sheet 1), are being dry-proofed and are almost ready for engraving. Meanwhile a considerable number of six-inch Sheets are being engraved and twelve are published. The district represented in these Sheets is principally the Scremerston and Lickar coalfield of Lower Carboniferous age. It contains considerable reserves of coals, but these are not of high quality and have hitherto been worked only locally and on a small scale. The survey is proceeding southwards into the Alnwick (6) and Rothbury (9) Sheets, where the valuable Shilbottle Coal occurs. A certain amount of revision work has also been done in the vicinity of Newcastle and Gateshead (Sheet 20), where the rocks belong to the Coal Measures and the coal deposits are of great importance. It has been found that though the old maps are accurate they can be greatly improved and much new information is being collected. Every assistance is being given by the mining companies, and as the pits and bores in this district are very numerous it is possible to attain a fairly complete knowledge of the structure and succession in this coalfield.

After careful consideration of the progress of mapping in Scotland it has been decided that in 1924 work in the coalfields will be pushed forward and the original six-inch survey of the Highlands will be slowed down for a time. This policy led to modifications in the work during 1923, which consisted principally in finishing off those Sheets which could be completed and

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published immediately and concentrating work on coalfield revision where circumstances permitted it. In the Western Highlands Mr. Bailey and Mr. Richey were engaged in finishing the survey of Ardnamurchan (Sheets 52 and 51), a highly complex volcanic centre resembling that of Mull in many respects. Mr. Bailey reports that this work is finished and when the necessary petrographical and chemical investigations have been completed the publication of Sheets 42 and 51 (Tiree and Coll with Ardnamurchan) can be undertaken. The one-inch map of Central Mull (Sheet 44) has been published. Iona and Staffa with Western Mull (Sheet 43) is being engraved. The memoirs on these maps are in the press or in manuscript and will be published in 1924. The survey of Mull has been a task of extraordinary complexity and difficulty and it is expected that the results will prove of considerable scientific interest. Although resembling Skye in many respects the structure of Mull is much more intricate and the published one-inch map exhibits a complexity which makes it an object lesson in the mapping of volcanic districts.

The survey of the Ayrshire coalfield is being rapidly advanced and the publication of the results is now making steady progress. As will be seen from the particulars given at the end of this report, twenty-two six-inch maps of the Ayrshire coalfield were published in 1923 and six are being engraved. This brings the publication of the North Ayrshire six-inch survey very nearly abreast of survey and places the revision of the Kilwinning, Troon, Kilmarnock and Hurlford districts at the service of the public. The corresponding one-inch Sheet 22 will now be dry-proofed, but as it is a difficult Sheet it will probably not be issued before the end of 1925. Economic memoirs on the Ayrshire coalfield similar to those that have been issued for the Central Coalfield of Scotland are now in preparation. North Ayrshire will be described in two parts, of which the first is ready for the press and the second is in manuscript but still needs editing. Sheets of vertical sections for these areas are to be published, colour-printed, and are now in preparation. Meanwhile the revision of the Kilmarnock one-inch Sheet is practically finished and a considerable area of the Sheet to the south (Ayr, Sheet 14) has been revised. This includes most of the concealed coalfield of Ayrshire, which lies below the red rocks of the Mauchline district, and contains important coal seams as yet unworked.

Mr. Murray Macgregor and his staff have been at work in the North-East Highlands and the Central Coalfield. The Brora and Helmsdale Sheet (103) has been re-examined so far as was desirable before publishing it in a colour-printed edition, with drift in stipple, such as is now issued for Highland districts. This Sheet and the adjacent Sheet to the west (Lairg, Sheet 102) are being engraved and the corresponding memoirs are being written. In the Altnaharra Sheet (108), which lies to the north, a little work has been done in 1923, but there was no possibility of completing this Sheet during the field season.

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The Central Coalfield of Scotland continues to receive attention, for, although the revision is finished, publication is not yet accomplished. It is gratifying to be able to report that the six-inch revised maps, with one or two exceptions, are now published. The one-inch map of the north-east part of this coalfield (Falkirk, Sheet 31) is being printed off at the Ordnance Survey Office and will be on sale in 1924. Two editions are to be issued, 'solid' and 'drift,' a step which was necessary owing to the complexity of the geology and the great amount of detail shown on the map. Nine six-inch maps of this coalfield were published in 1923. The economic memoir on the Bathgate area is passing through the press and new editions of the Glasgow memoir and the economic memoir on the Airdrie district (Area V) have been in preparation. Many bores have been inspected in this and the adjacent coalfields during the year and the information is being kept thoroughly up to date. With the completion of the revision of the Central Coalfield attention has been diverted to the outlying coalfields such as Muirkirk, Douglas and Clackmannan. The revision of the Muirkirk area is now well advanced, but the maps are not yet ready for dry-proofing. The Stirling, Clackmannan and Alloa fields are also nearly completely revised, but much mining information has yet to be investigated and finally reduced. Some of the six-inch maps of these fields are now with the engravers. Some work has also been done in the Douglas field, but the difficulties there are considerable. Owing to the great variation in the sequence, the abundance of faults and the isolated position of these minor coalfields, great care must be taken in the correlation, and the interpretation of bore-sections is often very difficult. The unit working in Fifeshire has now been able to correlate the sequence of the Central and Alloa coalfields with Fife, an achievement which marks a great step in advance in the knowledge of the Scottish Carboniferous.

The collection and publication of information regarding the metalliferous deposits and economic minerals of Great Britain has continued to receive attention in all the districts in which mining is in progress. As will be seen from the list of publications appended to this report, five volumes of the Special Reports on the Mineral Resources of Great Britain have been issued during 1923. Two of these (Tungsten Ores and Fluorspar) were third editions brought up to date. Two others complete the series of reports on Lead and Zinc Ores and the fifth is on Copper Ores. Several volumes are in preparation, including a second edition of the report on the Hæmatite Ores of Cumberland. An account of British Iron Ores from the standpoint of their mineralogy and chemistry is in manuscript and a similar report on Fireclays is in the press. A second report on Copper Ores will also be issued. Periodical visits are paid to the active metalliferous mines in order to collect information. These Special Reports have been welcomed by the mining and geological public, as undoubtedly they fill a gap in the literature

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of the subject and are of value as founded on personal inspection and direct knowledge of the deposits.

No water supply memoirs have been published during 1923, but voluminous manuscripts on the water supply of Wiltshire and Dorset, by Mr. Whitaker, and on Gloucestershire, by Mr. L. Richardson, are completed and deposited in the office. At the present high prices of publication it seems inadvisable to print these memoirs in full, and the task of selecting the important details and reducing the size of the volumes is a critical one; consequently until a competent editor is available printing is suspended, but the manuscripts are of much use to the staff and are open for consultation by the public. The memoirs on the water supply of other counties that have been put in hand during the year are Derbyshire, by Mr. J. B. Hill, and Worcestershire, by Mr. Richardson. A memoir on the water supply of Somersetshire was commenced by Mr. Whitaker, but owing to ill-health he has been unable to complete it and arrangements have been made with Mr. Richardson to serve as joint author. These manuscripts were in progress at the close of the year.

The records of borings for water, especially in the south-east of England, are being constantly increased in number by contributions from engineers, borers, water authorities and others. Much of this information is checked by visits to the site of the bore, inspection of cores and collecting fossils. Borings for minerals and coals are also frequently reported to the Survey and in each District the District Geologist has charge of the records. So far as other duties will allow all critical or important bores are visited once or oftener by a geologist who is competent to verify the record and discuss points of difficulty that may arise.

The work of the drawing office both in England and in Scotland has included the preparation of a large number of dry-proofs and standard copies of six-inch maps and one-inch maps, of illustrations for the memoirs, graphic sections of bores, and hand-coloured copies to serve as patterns for the colour-printer or for the hand-colouring of six-inch maps. Much attention has been given to the six-inch coalfield maps in order to ensure that publication should not be delayed too long after the completion of the survey. During 1923 there has been a marked advance in the publication of the six-inch maps of Ayrshire, Northumberland and the North Wales coalfield. The arrears of publication of six-inch maps are now comparatively light and in another year the state of publication will be still further improved.

Five English colour-printed one-inch maps were published during 1923 and nine Scottish one-inch maps. This work is now nearly all done by a six-colour process which reduces the number of printings required by the processes formerly employed and accelerates publication. For several years the six-colour process was in use for Scottish maps, but it has now been extended to the English maps. Great care and judgment are necessary if satis-

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factory results are to be obtained, but as experience is gained the difficulties are being overcome and some of the recent maps such as Mull (Sheet 44) are good examples of colour-printing. Most of the maps recently published are new maps or completely revised editions of maps formerly issued in hand-coloured form. Among them are three Sheets of the Silurian country in the South of Scotland, showing the graptolite zones mapped by Dr. Horne and Dr. Peach and containing also a revised nomenclature of the dyke rocks. New standards of the six-inch maps of that district are being prepared in Edinburgh for public reference and are checked by Dr. Peach and Dr. Horne on completion.

Four parts of Dr. Kidston's great monograph of the Carboniferous Fossil Plants of Great Britain have been issued during the year. A fifth part is in manuscript and a sixth part in preparation. Ninety-one collotype plates of excellent quality illustrate the text matter of the first four parts. This work will be for many years a standard treatise on the subject and fills a notable gap in palæobotanical literature. By its publication the Geological Survey of Great Britain is performing a service of the highest value not only to British botanists and geologists but to all interested in coals of Carboniferous age in any part of the world. Another publication in which palæontology takes a large part is the memoir on the Concealed Mesozoic Rocks in Kent: the careful scientific investigation of these rocks is of high importance to geologists and will probably have some influence in directing the search for suitable areas for mining development. The Survey continues to collect information from the bores and shafts in this coalfield, as occasion offers.

In April the Museum was closed to the public owing to the condition of the roof and at the end of the year was still closed. A timber structure supporting the roof has been erected at the north end of the Museum, but no repairs have been executed. Many enquiries have been received from individuals, schools and societies, as to the probable date of re-opening, but to these it is impossible to give a satisfactory reply. The library and offices of the Survey have been kept open to the public till November, when the library was closed for repainting. As far as possible the indoor work of the Survey and Museum has been carried on as usual, in spite of the disorder and dilapidation of the Museum.

I.—SURVEY WORK

(1)—ENGLAND AND WALES

Field-work

London and South-Eastern District.—Field survey was completed in Sheet 257 (Romford) by Messrs. Dines and Edmunds, with Mr. Dewey as District Geologist.

The survey of the Jurassic and revision of Upper Cretaceous rocks around Calne and Wootton Bassett in order to complete the six-inch

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survey of Sheet 266 (Marlborough) was commenced by Messrs. Dines, Edmunds and Edwards.

Midland District.—Work was continued in Sheet 153 (Wolverhampton) and in Sheet 167 (Dudley) by Messrs. Pocock, Whitehead and Robertson, under the superintendence of Mr. Cantrill, District Geologist.

Yorkshire District.—Work was commenced in Sheet 77 (Huddersfield) by Messrs. Wray, Stephens, Edwards and Bromehead, with the last-named as District Geologist.

Mr. Wilson, under the general supervision of Dr. Gibson, was engaged in bringing up to date information concerning the Concealed Coalfield of Yorkshire, Derbyshire and Nottinghamshire.

Lancashire District.—The survey of Sheet 76 (Rochdale) was practically completed by Mr. Wright, District Geologist, and Messrs. Sherlock, Lloyd, Tonks and Jones.

Cumberland District.—Work was continued in Sheet 18 (Brampton), Sheet 28 (Whitehaven), and commenced in Sheet 12 (Shopford) by Messrs. Dixon, Eastwood, Trotter and Hollingworth, under the superintendence of Mr. Bernard Smith. Mr. Smith also examined many mines and borings in the hæmatite area of Cumberland and Furness.

Northumberland and Durham District.—Work was continued in Sheets 6 (Alnwick), 9 (Rothbury), 14 (Morpeth), 20 (Newcastle-on-Tyne) by Mr. Carruthers, District Geologist, with Messrs. Burnett, Maden, Fowler and W. Anderson.

Indoor Work

The manuscripts of the following memoirs are being written or edited for publication :—

Special Reports on the Mineral Resources of Great Britain :—

Copper Ores of the Midlands, the Lake District, and North Wales.
Refractory Materials : Fireclays. Chemistry and Physical Tests.
Iron Ores : Petrography and Chemistry.
Iron Ores : Hæmatites of West Cumberland, Lancashire, and the Lake District (2nd Edition).

Water Supply of Wiltshire ; of Gloucestershire ; of Dorsetshire ; of Worcestershire ; and of Derbyshire.

Palæontology. Vol. II. Fossil Plants of the Carboniferous Rocks of Great Britain. Part 5.

Explanations of Sheets 11 (Longtown), 16 (Silloth), 17 (Carlisle), 138 (Wem), 168 (Birmingham), 239 (Hertford), 256 (North London), 266 (Marlborough), 271 (Dartford).

Concealed Coalfield of Yorkshire, Derbyshire and Nottinghamshire (2nd Edition).

The following maps and memoirs were published or passing through the press in 1923 :—

I.—MAPS

Published.

1 inch to 1 mile :—
Sheet 96 (Liverpool, drift and solid editions), Sheet 169 (Coventry, drift edition), Sheet 238 (Aylesbury, drift edition), Sheet 313 (Shaftesbury, drift edition).

6 inches to 1 mile :—
Cheshire (30 N.W. and 30A N.E.), 30 N.E.
Denbighshire, 20 N.E. (Flint 16 N.E.), S.E. (Flint 16 S.E.) ; 21 S.W. (Flint 17 S.W.), S.E. (Flint 17 S.E.).

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Flintshire, 2 N.W., (2 N.E. and 2A S.E.), 2 S.W., S.E.; 3 S.W.; 5 N.E.; 6 N.W., N.E., S.W., S.E.; 9 N.E., S.E.; 10 N.W., S.W., S.E.; 13 N.E., S.E. (Denbigh 15 S.E.); 14 N.W., N.E., S.W.; 17 N.W.

Leicestershire, 28 N.W. (Staffs. 60 N.W.; Warw. 3 N.W.).

Northumberland, 4 N.W., S.W.; 7 N.W.; 10 N.E., S.E.; 11 N.W., N.E., S.W., S.E.; 15 N.W., N.E.; 22 S.E.

Warwickshire, 3 S.W. (Leics. 28 S.W.); 6 N.W. (Leics. 34 N.W.), 6 S.W.

In the press, engraving or colour-printing.

1 inch to 1 mile :—

Sheet 16 (Silloth), Sheet 17 (Carlisle), Sheet 108 (Flint), Sheet 138 (Wem), Sheet 168 (Birmingham), Sheet 239 (Hertford), Sheet 271 (Dartford), Sheet 318 (Brighton), Sheet 333 (Worthing).

6 inches to 1 mile :—

Cumberland, 61 S.E.; 67 N.W. (New Ed.), S.W. (New Ed.); 72 N.W.

Northumberland, 15 S.E.; 17 (S.W. and S.E.); 20 N.W., N.E., S.E.; 21 N.W., N.E., S.W., S.E.

Staffordshire, 62 S.E.; 67 N.E., S.E. (Worcs. 1 S.E.); 68 N.W., N.E., S.W. (Worcs. 2 S.W.), S.E. (Warw. 7 S.E.); 71 N.E. (Worcs. 4 N.E.), S.E. (Worcs. 4 S.E.); 72 N.W. (Worcs. 5 N.W.), S.W. (Warw. 13 S.W.; Worcs. 5 S.W.).

Worcestershire, 9 N.E.; 10 N.W., N.E., S.W.

Copies of the following six-inch sheets, which are not to be published, were deposited in the Library for public reference :—

Buckinghamshire, 42 S.E.; 43 S.W.; 47 S.E.; 48 N.W., N.E., S.W., S.E.; 52 N.E., S.E. (Berks. 24 S.E.); 53 N.W.

Cumberland, 13A S.E.; (14 N.W. and 9B S.W.), (14 N.E. and 9B S.E.), 14 S.W., S.E.; 20 N.E., (S.W. and S.E.), 21 N.W., N.E., S.W., S.E.; 27 N.W., N.E.; 28 N.W., N.E.

Essex, 83 N.W., N.E., S.W., S.E.; 84 N.W., N.E., S.W., S.E. (part).

Hertfordshire, 21 S.W., S.E.; 22 S.W.; 29 N.W., N.E., S.W., S.E.; 30 N.W., S.W.; 36 N.W., N.E., S.W., S.E.; 37 N.W., S.W.; 38 S.W., S.E.; 42 N.W.; 43 N.W., N.E., S.E. (Middx. 4 S.E.); 44 N.W.

Kent (1A S.E. and 2 N.E.); 2 N.W.; 3 N.W., S.W.; 9 N.W., N.E., S.E.; 10 N.W., N.E., S.W., S.E.; 16 N.W., N.E., S.W., S.E.; 17 N.W., N.E., S.W., S.E.; 18 N.W., N.E., S.W., S.E.; 27 N.E.; 28 N.W., N.E.; 29 N.W., N.E.; 30 N.W., N.E.

Middlesex, 2 N.W. (Herts. 41 N.W.), N.E. (Herts. 41 N.E.), S.W. (Herts. 41 S.W.).

Staffordshire, 72 N.E. (Warw. 13 N.E.; Worcs. 5 N.E.), S.E. (Warw. 13 S.E.; Worcs. 5 S.E.).

Warwickshire, 8 N.W. (Staffs. 69 N.W.), N.E., S.W. (Staffs. 69 S.W.), S.E.; 9 N.W., S.W.; 14 N.W., N.E., S.W., S.E.; 15 N.W., S.W.; 19 N.W. (Worcs. 11 N.W.), N.E. (Worcs. 11 N.E.), S.W. (Worcs. 11 S.W.), S.E.; 20 N.W., S.W.

Worcestershire, 10 S.E.

II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1922. 164 pp.; 6 text-figures. 1923. Price 4s. net.

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Special Reports on the Mineral Resources of Great Britain :—

Vol. I.—Tungsten and Manganese Ores. By Henry Dewey and H. G. Dines, A.R.S.M., A.M.Inst.C.E., with contributions by C. N. Bromehead, B.A., T. Eastwood, A.R.C.S., G. V. Wilson, B.Sc., and R. W. Pocock, B.Sc. 83 pp.; 3 plates. *Third Edition.* 1923. Price 2s. net.

Vol. IV.—Fluorspar. By R. G. Carruthers and R. W. Pocock, B.Sc., with contributions by D. A. Wray, M.Sc., Henry Dewey and C. E. N. Bromehead, B.A. 42 pp.; 1 plate. *Third Edition.* 1922. Price 1s. 6d. net.

Vol. XXV.—Lead and Zinc Ores of Northumberland and Alston Moor. By Stanley Smith, M.A., D.Sc., with contributions by R. G. Carruthers. 110 pp.; 15 plates. 1923. Price 3s. 6d. net.

Vol. XXVI.—Lead and Zinc Ores of Durham, Yorkshire and Derbyshire, with Notes on the Isle of Man. By R. G. Carruthers and Sir Aubrey Strahan, K.B.E., F.R.S. 114 pp.; 2 plates; 6 text-figures. 1923. Price 3s. net.

Vol. XXVII.—Copper Ores of Cornwall and Devon. By Henry Dewey. 76 pp.; 4 plates; 13 text-figures. 1923. Price 2s. 6d. net.

Monograph on the Fossil Plants of the Carboniferous Rocks of Great Britain. (Palæontology. Vol. II.) By Robert Kidston, LL.D., D.Sc., F.R.S., L. & E., F.G.S.

Part 1.—110 pp.; 22 plates. 4to. 1923. Price 15s. net.
Part 2.—88 pp.; 25 plates. 4to. 1923. Price 12s. 6d. net.
Part 3.—76 pp.; 21 plates. 4to. 1923. Price 12s. 6d. net.
Part 4.—102 pp.; 23 plates. 4to. 1923. Price 15s. net.

The Concealed Mesozoic Rocks in Kent. By G. W. Lamplugh, F.R.S., F. L. Kitchin, M.A., Ph.D., and J. Pringle. 248 pp.; 2 plates; 5 text-figures. 1923. Price 7s. 6d. net.

The Geology of Liverpool with Wirral and part of the Flintshire Coalfield. (Explanation of one-inch Sheet 96.) By C. B. Wedd, B.A., Bernard Smith, M.A., W. C. Simmons, B.Sc., A.R.C.Sc., and D. A. Wray, M.Sc. 183 pp.; 2 plates; 6 text-figures. 1923. Price 4s. net.

The Geology of the Country around Coventry, including an account of the Carboniferous Rocks of the Warwickshire Coalfield. (Explanation of one-inch Sheet 169.) By T. Eastwood, A.R.C.Sc., W. Gibson, D.Sc., T. C. Cantrill, B.Sc., and T. H. Whitehead, M.Sc., A.R.C.Sc., with contributions by H. H. Thomas, M.A., Sc.D., and the late C. H. Cunnington, B.Sc. 149 pp.; 8 plates; 5 text-figures. 1923. Price 5s. net.

The Geology of the Country around Aylesbury and Hemel Hempstead, (Explanation of one-inch Sheet 238.) By R. L. Sherlock, D.Sc., A.R.C.Sc., with contributions by J. Pringle, C. P. Chatwin, and R. W. Pocock, B.Sc. 66 pp.; 1 plate; 1 text-figure. 1922. Price 2s. net.

The Geology of the Country South and West of Shaftesbury. (Explanation of one-inch Sheet 313.) By H. J. Osborne White, F.G.S. 112 pp.; 4 plates; 11 text-figures. 1923. Price 3s. 6d. net.

Guide to the Collection of Gemstones in the Museum of Practical Geology. By W. F. P. McLintock, D.Sc. 80 pp.; 24 text-figures. *Second Edition.* 1923. Price 1s. net.

In the press.

The Geology of the Country around Flint, Hawarden and Caergwrle. (Explanation of one-inch Sheet 108.)

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The Geology of the Country near Brighton and Worthing. (Explanation of one-inch Sheets 318 and 333.)
The Geology of the Thames Valley near Goring, as illustrated by the Model in the Museum of Practical Geology.

(2)—SCOTLAND

Field-work

Following instructions to effect concentration on Coalfield work, survey work in the Highlands was restricted to completing nearly finished sheets. Considerable progress in consequence has been made with the survey of the Ayrshire coalfield, and that of Fifeshire was begun.

West Highlands.—Along the western borders of Sheet 52 (Ardnamurchan) the examination of the Igneous Complex has been completed by Mr. Richey under Mr. E. B. Bailey, District Geologist.

North-East Highlands.—Under Mr. M. Macgregor, District Geologist, Messrs. Read, Ross and Phemister completed the revision of Sheet 103 (Brora) and continued the survey of Sheet 108 (Altnaharra).

Ayrshire.—Mr. Bailey, District Geologist, and Messrs. Richey, Eyles, Simpson and A. G. MacGregor have continued survey work in Sheets 22 (Kilmarnock), and 14 (Ayr).

Lanarkshire (including Muirkirk).—Mr. M. Macgregor, District Geologist, and Messrs. E. M. Anderson, Ross and Phemister, have continued the revision of Sheets 15 (Muirkirk), and 23 (Lanark).

Fifeshire.—Mr. Dinham with Messrs. Haldane, Allan and Knox, have commenced the survey of Sheet 40 (Dunfermline).

Indoor Work

The manuscripts of the following memoirs are being written or prepared for publication :—

Economic Geology of the Central Coalfield of Scotland :—
Area V.—(Glasgow East, Chryston, Glenboig and Airdrie) *Second Edition.*
Economic Geology of the Ayrshire Coalfield :—
Area I.—(Dalry, Saltcoats, Kilwinning and Kilmaurs)
Area II.—(Irvine, Kilmarnock, and Newmilns)
The Geology of the Glasgow District. *Second Edition.*
Explanation of Sheet 102 (Lairg).
The Pre-Tertiary Geology of Mull, Loch Aline, and Oban.

The following maps and memoirs were published or passing through the press in 1923 :—

I.—MAPS

Published.

1 inch to 1 mile :—

Special Map of Assynt District, Sheet 86 (Huntly), Sheet 96 (Banff), Sheet 84 (Lower Findhorn and Lower Strathnairn), Sheet 54 (Moor of Rannoch), Sheet 44 (Mull), Sheet 3 (Stranraer, Port Patrick), Sheet 2 (Whithorn, Burrow Head), Sheet 1 (Mull of Galloway).

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6 inches to 1 mile :—
Ayrshire, 7 N.E., S.E.; 8 N.W., S.W., S.E.; 11 N.W., S.W., S.E.; 12 S.W.; 16 (N.W. and S.W.), 16 N.E., S.E.; 17 N.W., N.E., S.W., S.E.; 18 N.W., S.E.; 22 N.W., N.E.; 23 N.W., N.E.
Lanarkshire, 18 N.W.
Renfrewshire, 15 N.W.
Stirlingshire, 23 S.E.; 28 S.E.; 29 N.W., S.W.; 33 N.E. (Dumb. det.)
Perthshire and Clackmannanshire, 140 N.W., S.W.

In the press, engraving or colour-printing.

1 inch to 1 mile :—
Sheet 103 (Brora), Sheet 102 (Lairg), Sheet 43 (Iona), Sheet 31 (Falkirk), Sheet 16 (Moffat), Sheet 4 (Wigtown).
6 inches to 1 mile :—
Ayrshire, 12 N.E., S.E.; 13 N.W., S.W., S.E.; 18 S.W.

Copies of the following six-inch sheets, which are not to be published, were deposited in the Office for public reference :—

Ayrshire, 48; 53 N.W., N.E., S.W.; 54 N.W., N.E.
Dumfriesshire, 29 N.E., S.E.; 30.
Kirkcudbrightshire, 1 N.E., S.E.; 2; 3; 4 N.E., S.E.; 6; 9; 10; 11 S.W.; 15; 17; 18 S.W., S.E.; 19 S.W.; 38; 53 N.E.; 55 N.W., N.E.
Ross-shire and Cromartyshire, 10 N.W., S.W., S.E.; 11 S.W., S.E.; 11A S.W.; 16; 17; 18; 18A S.W.
Sutherlandshire, 84; 85; 93; 94; 100 N.E., S.E.; 101; 102; 103; 107 N.E., S.E.; 108.

II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain for 1922. *See* p. 15.

The Geology of the Lower Findhorn and Lower Strath Nairn, including part of the Black Isle near Fortrose. (Explanation of Sheet 84 and part of Sheet 94 Scotland.) By John Horne, LL.D., F.R.S.; with contributions by B. N. Peach, LL.D., F.R.S.; L. W. Hinxman, B.A., F.R.S.E.; R. G. Carruthers, F.R.S.E.; and E. M. Anderson, M.A., B.Sc.; and a Petrographical Chapter by John S. Flett, D.Sc., LL.D., F.R.S. 128 pp.; 3 text-figures. 1923. Price 5s. net.

The Geology of Corrour and the Moor of Rannoch. (Explanation of Sheet 54.) By L. W. Hinxman, B.A., F.R.S.E.; and M. Macgregor, M.A., B.Sc., F.R.S.E.; with contributions by the late Dr. C. T. Clough, F.R.S.E.; and Petrological Notes by Herbert H. Thomas, M.A., Sc.D.; and H. H. Read, M.Sc., A.R.C.Sc. 96 pp.; 6 text-figures. 1923. Price 4s. net.

In the press.

The Geology of the Country round Banff, Huntly and Turriff. (Explanation of Sheet 86 and Sheet 96.)
The Economic Geology of the Central Coalfield of Scotland :—
Area VI.—(Bathgate, Wilsontown and Shotts).
The Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Oban (being Part II. of Explanation of Sheet 44—Oban and Mull)

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Further progress has been made with the new exhibits of Jurassic fossils in the Survey Gallery, Royal Scottish Museum. Thanks to the Museum authorities having allocated to the Survey the use of the Northern side of the gallery the exhibits illustrating Devonian fossils upwards now form an unbroken unit.

II.—GENERAL WORK

A.—PETROGRAPHICAL DEPARTMENT

In addition to the routine work of the Petrographical Department, Dr. Thomas has been mainly concerned with the petrology of Sheets 51 and 52 Scotland (Ardnamurchan), Sheet 43 (Ross of Mull) and Sheet 44 (Mull) now passing through the press. For the purpose of co-operating with Mr. Richey in the petrographical account of Sheets 51 and 52, he visited Ardnamurchan in the early summer. He continued his work on the source of the Stonehenge monoliths and an account has been published by the Society of Antiquaries.

For the Mines Department an investigation was carried out to ascertain the mineralogical constitution of 70 samples of dust used in mines for the prevention of explosions.

The numbers of rocks sliced, or in progress of slicing, registered in the collections to the end of the year were :—

English	... ...	12,539
Scottish	... ...	22,827
Irish	... ...	445
Foreign	... ...	2,501
	Total	38,312

This represents an increase of 1,578 in the registered rocks. Of the corresponding sections 580 were made in the English Office, 351 in the Scottish Office and 324 by private individuals—leaving 323 yet to be prepared.

The official and extra-official calls upon the collections continue to be heavy, 2,090 rocks and sections having been dispatched on loan to Survey officers and others for the purpose of study.

The petrology of Sheet 102 (Lairg) and 103 (Brora) is being prepared by Messrs. Read and Phemister : in Sheet 22 (Kilmarnock) Messrs. Richey and A. G. MacGregor are collaborating with the petrographer.

One hundred and sixty private rock slides from Sheets 86 and 96 (Huntly and Portsoy) were presented by Dr. John Horne.

Rock specimens were collected during the year to the number of 2,125 from the following one-inch maps :—

> Sheet 5 (Kirkcudbrightshire) ; Sheet 14 (Ayrshire) ; Sheets 31, 23 (Lanarkshire) ; Sheets 42, 51 and 52 (Argyllshire) ; Sheet 39 (Fifeshire) ; Sheet 6 (Linlithgowshire).

Rock sections to the number of 351 were made by Mr. Eckford, which, together with 346 made in 1922, have been registered and added to the collection.

In the Survey Gallery, Royal Scottish Museum, an exhibit to illustrate the geology of Sheets 86 and 96 (Banff, Huntly and Turriff) was prepared

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under the supervision of Mr. H. H. Read; another exhibit under the supervision of Mr. E. B. Bailey, to illustrate the geology of Sheets 43 and 44 (Mull) is in preparation.

B.—PALÆONTOLOGICAL DEPARTMENT

England and Wales

During the year, 3,882 specimens were added to the collections. The donations included a fine series of plants from the Coal Measures of various localities in the South Wales coalfield, presented by Mr. David Davies of Gilfach Goch. These have been examined and named by Dr. R. Kidston. Fossil-collecting has been carried on chiefly in Cumberland, Lancashire, Staffordshire, Shropshire and the counties around London, in connexion with the current work of the Survey. The examination of these collections has proceeded.

Mr. Pringle has made visits to deep borings in Kent, Norfolk and Staffordshire; he has examined sections in the Jurassic rocks in Wiltshire and has rendered other assistance in the revision of the Marlborough Sheet (266).

Mr. Chatwin has visited sections in the Chalk in Kent and has contributed an account of the Chalk to the Dartford memoir (Sheet 271) now in preparation. He has also named a series of fossils from the Chalk of Hertfordshire and has written a chapter on the Chalk for the memoir on Sheet 239.

The officers of the department have spent much time in editorial work, in addition to carrying out palæontological investigations connected with the preparation of memoirs. They have also dealt with many enquiries of an economic character and have given assistance to numerous visitors engaged in special researches. Upwards of 3,000 specimens of fossils have been sent out on loan for examination by research-workers.

Scotland

During the year the number of fossils collected and registered amounted to 3,806. All are from the Carboniferous rocks of Scotland, collected chiefly from natural exposures in connexion with current field work; a few were obtained from borings for coal.

C.—CHEMICAL DEPARTMENT

In 1923, the quantitative analyses of twenty-three rock samples were completed. This number includes the analyses of two iron ores for the memoir on British Sedimentary Iron Ores, one sand of possible commercial value (Optical Glass Industry), and one specimen from Canada. The remaining analyses were of igneous rocks.

Five qualitative examinations were made for Survey officers.

Mr. F. R. Ennos was transferred on 22nd September, 1923, to H.M. Custom House Laboratory.

Mr. B. E. Dixon, B.Sc.(Lond.), A.I.C., has been seconded from the Government Laboratory for duty at the Geological Survey Laboratory.

D.—PHOTOGRAPHIC WORK

Mr. J. Rhodes during the year has taken 270 views of geological subjects, mainly illustrative of the geology of Sussex and Lancashire. Photo-micrographs have been prepared to the number of 33, and miscellaneous

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photographs 291. Other work consisted in the preparation of 85 lantern-slides, 32 enlargements, and 1,162 direct prints of which over 1,000 have been mounted.

The number of negatives now registered is as follows :—

English Photographs	2,509
Photomicrographs	1,268
Miscellaneous	1,212
Total	4,989

In Scotland 63 views of geological interest were photographed in Argyllshire (Sheets 51 and 52) and 4 in Fifeshire (Sheet 32).

The sale of prints and lantern slides to the public during the year was 170 prints and 35 lantern slides.

A series of photographs of micro-sections of various oil-shales has been presented by Mr. D. R. Steuart of Broxburn.

III.—MUSEUM OF PRACTICAL GEOLOGY

Owing to the condition of the roof and the repairs necessary to render it safe, the Museum has been closed to the public since April 12th, and on November 6th, the Library, Map Room and Palæontological Department had to be closed for repainting. Work on the exhibited collections and to a certain extent in the stores had, in consequence, to be largely suspended.

A new edition of the Guide to the Collection of Gemstones has been issued.

The Curator visited the Meldon Quarry, Okehampton, Devonshire, and examined the occurrence there of the rare mineral petalite. The results of the investigation have since been published.

An exhibit was prepared for the Sixth International Mining Exhibition held in May.

In the Mineral Department progress has been made with the work of cleaning and registration, the contents of Wall Cases 23, 24, 43–47 having been dealt with. The Card Catalogue of the Inventory has been completed to date and 643 specimens have been added to the Mineral Inventory. The collection and investigation of the Iron Ores have been continued.

The additions to the Library comprise 189 volumes of independent works, 2,372 volumes and parts of serials, 371 maps and 102 pamphlets; and 350 photographs were added to the collection. To relieve congestion in the Library 1,100 volumes have been removed to an annexe.

List of Donations during the Year 1923

Ashcroft, F. N., Esq., M.A., F.C.S., F.G.S.—Specimen of epidote with amphibole asbestos, and adularia on weathered amphibolite, from Alp Russein, Grisons, Switzerland; a series of mineral specimens from Switzerland; two crystals of ilmenorutile from Madagascar.

Associated Portland Cement Manufacturers (1900) Ltd., per H. Cox, Esq.—Two Ammonites from the Lower Chalk of Burham, Kent.

Bertodano, Charles E., Esq.—Collection of silver ores, etc., from Hiela-cienda Mine, Spain.

Bolton, F., Esq., M.I.C.E.—Two specimens of massive vesuvianite.

Boram, Hurst, Esq.—A large series of asbestos specimens.

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BROWN, E. E. S., ESQ.—Two specimens *Cyrena spp.* from the Woolwich Beds in the new Watling Street section through Shorne Wood, near Cobham, Kent.

CARTER, VILLIERS, ESQ.—Specimen of gum, from Ameki, Nigeria.

CROFTON, CECIL F., ESQ.—Sapphire in ring and cameo in chrysoprase; specimens of malachite, fluor, calcite and quartz.

DAVIES, D., ESQ., M.Sc., F.G.S.—A fine series of Plants from the Coal Measures of various localities in the South Wales Coalfield.

DAVIS, A. G., ESQ.—A specimen of *Ophioglypha wetherelli* Busk, from the London Clay at Tolworth Brickyard, near Surbiton; and four Brachiopods from various zones of the Chalk at Merstham, Surrey.

GRINDLEY, REV. H. E., M.A., F.G.S.—A series of 52 specimens of fossil Fish-remains from the Old Red Sandstone of the Pontrilas district, Herefordshire.

HAHN, E., AND COMPANY, LTD.—Iron pyrites cut for jewellery.

HARRIS, CAPT. GUY, R.A.F.—A fine specimen and counterpart of *Cordaites principalis* (Germar), from the Boulder Clay, west of Howden, Yorkshire.

HAWKINS, PROF. H. L., D.Sc.—A specimen of *Phillipsia laticaudata*? H. Woodw., from the Carboniferous Limestone of Worsaw Hill, near Clitheroe (collected by E. Moore, Esq., of Haslingden, Manchester).

HEATON, NOEL, ESQ., B.Sc., F.C.S.—Ilmenite from Egersund, Stavanger, Norway; and a mixture of titanic acid and ferrous sulphate obtained from the powdered ilmenite by treatment with sulphuric acid and subsequent extraction with water.

HINDERLICH, A., ESQ.—A series of minerals used as crystals in 'wireless.'

HODGE, J., ESQ.—White opal from Dartmoor.

KITCHIN, F. L., ESQ., Sc.D., Ph.D., and PRINGLE, J., ESQ., F.G.S.—A series of fossils and rock-specimens from the Lower Greensand, Gault and Lower Chalk of various counties in England.

LINGWOOD, EDWARD T., ESQ.—Plaster model of a flint mine at Brandon, Suffolk.

MALCOLM, C. W., ESQ.—Rock salt with overlying marl from Heath Lane Shaft, Winsford, Cheshire.

MONCRIEFF, H. A., ESQ.—Five specimens and a micro-slide of *Nummulites* from the Bracklesham Beds of Bracklesham; and three cut and polished specimens of *Siphonia*, from the beach (derived from the Upper Greensand, Chert Beds) at the east end of Ventnor, Isle of Wight.

PRINGLE, JOHN, ESQ., F.G.S.—A specimen of '*Perisphinctes*' *sp.* from the Pseudogigas Zone (Cockly Bed), Portland Stone Series, Okus Quarry, Swindon; and a specimen of *Physodoceras lallierianum* (d'Orb.), from the Kimmeridge Clay (*Aulacostephanus pseudomutabilis* Zone) at an excavation in the disused canal near Wharf Road, Swindon.

RUTHERFURD, W. G., ESQ.—Two agates cut and mounted; wristlet mounted with various ornamental stones.

SKINNINGTON IRON COMPANY, THE.—Cleveland magnesite and silica bricks.

UPTON, C., ESQ.—A series of 52 specimens of Cretaceous Cephalopods from various localities in the Southern Counties of England.

WOOLF, J., ESQ.—Sand cemented by calcite from the Canary Isles.

WRIGLEY, A., ESQ.—A specimen of *Streptochetus* (*Streptolathyrus*) *cymatodis* (Edw.), from the London Clay at Newnham, near Basingstoke.

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TABLE I

STATEMENT showing the NUMBER OF GEOLOGICAL MAPS and SECTIONS issued by the ORDNANCE SURVEY to AGENTS, etc., during the year ended 31st December, 1923.

Particulars.	United Kingdom.	England.	Scotland.	Total.
TWENTY-FIFTH-INCH TO THE MILE MAP OF THE BRITISH ISLES :—				
Colour-printed	375	—	—	375
QUARTER-INCH TO THE MILE MAPS :—				
Colour-printed	—	658	60	718
Uncoloured	—	—	—	—
ONE-INCH TO THE MILE MAPS :—				
Whole-sheets, Hand-coloured :—				
Solid	—	43	73	116
Drift	—	22	3	25
Colour-printed	—	—	286	286
Uncoloured	—	25	27	52
Quarter-sheets, Hand-coloured :— (Old Series)				
Solid	—	514	—	514
Drift	—	110	—	110
Quarter-sheets, Hand-coloured :— (New Series)				
Solid	—	—	—	—
Drift	—	—	—	—
Colour-printed :—				
Solid	—	27	—	27
Drift	—	1,476	—	1,476
SIX-INCHES TO THE MILE (COUNTY) MAPS :—				
Whole-sheets, Hand-coloured	—	131	20	151
Uncoloured	—	—	—	—
Quarter-sheets, Hand-coloured	—	52	5	57
Uncoloured	—	1,270	581	1,851
Horizontal Sections	—	121	2	123
Vertical Sections	—	150	5	155
Index to Colours and Signs	—	4	—	4
TOTALS	375	4,603	1,062	6,040

JOHN S. FLETT,
Director.

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SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1923

I.—INTRODUCTION

THE work of the Geological Survey of Great Britain in 1923 was directed principally to the revision of areas containing coal, iron or other minerals of economic importance. Most of the districts in which Survey work was being carried on are coalfields, actual or potential. A full and satisfactory knowledge of the sequence and structure in the various coal-bearing areas is of prime importance in framing estimates of our coal resources, and in directing the search for new seams and the exploitation of seams already known. Most of the principal coalfields have received attention during the year and though work of this class is of necessity very elaborate, requiring the most careful compilation and correlation of details, which entail slow progress if accuracy is to be attained, there is some satisfaction in knowing that the practical application of geological results is never out of mind.

In revising the coalfield maps, however, it is always necessary to consider also the strata which adjoin the coalfields, as when the maps are published they should as far as possible represent accurately the geology of the area shown on each Sheet according to the standards of the present day. This involves the examination of a great variety of rocks, including in the year 1923 strata from the pre-Cambrian to the most recent accumulations. Geological problems of all kinds have consequently to be investigated and as many of these are of considerable interest they sometimes bulk largely in the scientific results of the year's work as outlined in the annual ' Summary of Progress.'

An essential part of the Survey's work is also the collection of information regarding questions of public health, water supply from underground sources, metalliferous deposits, refractories, building stones and other rocks and minerals of economic value. In the South-East of England, for example, many problems arise which are essentially geological and the revision of the London area is yielding results that more than justify the work expended. In this district much of the ground was originally surveyed on the one-inch scale and the six-inch field maps now being prepared contain much geological information which it was impossible to show on the old survey.

The primary geological survey of Britain is not yet completed and a fairly large area in the North and West Highlands of Scotland has still to be officially surveyed. These districts are not densely populated and most of them are not known to contain valuable deposits of economic minerals; consequently their examination has been deferred till more urgent questions received attention,

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but field work in the Highlands has been carried on during part of each summer and the greater part of the Scottish Highlands is now published on the one-inch geological map.

The field work of the Survey is executed by units each consisting of a district geologist and several geologists, and the 'Summary of Progress' contains brief reports of the principal results obtained in each district. The reports are prepared by the district geologist from notes supplied by the field geologists. In addition there are reports of the palaeontologist, petrographer, chemist and curator of the Museum of Practical Geology. A few of the outstanding features of the year's work will be briefly reviewed in this introductory chapter to serve as an indication of points of special interest that have arisen in the ground surveyed.

The oldest rocks investigated are no doubt the Moine gneisses of the Eastern Highlands which form the interior of Sutherlandshire. These have well-defined characters over a wide area, and consist of various types of gneiss, granulite and quartzite. In the Helmsdale and Brora districts they are penetrated by a group of granitic rocks which show phenomena of permeation or interfusion at their margins, producing interesting types of synthetic gneiss. The granites also attack the older igneous rocks around them, giving rise to contaminated or mixed facies that are of great interest to petrographers.

Small inliers of old rocks occur among the coalfields of the Midlands of England, and halleflintas of the Uriconian and the Cambrian Hollybush Sandstone have been mapped by Mr. Whitehead at Lilleshall Hill in Shropshire. In Ennerdale, in Cumberland, the Skiddaw slates, which are practically unfossiliferous, have undergone contact alteration by the intrusive granophyre, and the latter rock shows a number of interesting variations which indicate differentiation of the parent mass. The only Silurian rocks that have been mapped during 1923 are in the Downtonian inlier near Linley Hall in Shropshire, where two bone-beds are known to occur.

Near the east coast of Sutherlandshire an extensive series of Middle Old Red Sandstone grits and conglomerates forms hill ranges rising to a height of over 2,000 feet. These are composed of materials derived from the underlying schists and are faulted against the Mesozoic rocks that form a low plain along the shore. On the boundaries of Ayrshire and Lanarkshire the Lower Old Red Sandstone is found in great thickness and has been penetrated by masses of granite and diorite which have produced intense contact alteration in the adjacent sediments. These sandstones pass down conformably into the Downtonian and Silurian rocks that form the Southern Uplands of Scotland.

The Lower Carboniferous hardly appears in the areas of coalfields surveyed during 1923 in the Midlands of England owing to overlap on to the basement platform, but in the North of England and Central Scotland this group has been the subject of much investigation

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by the field staff during the past year and many interesting results have been obtained. In Cumberland the sequence in the limestones, established during the previous two seasons, has been confirmed, and work has been begun on the east side of the Vale of Eden, near Brampton. A preliminary correlation of some important limestones in East and West Cumberland has been formulated and will be tested by further work. A few unimportant, though workable, coal seams occur in the limestone series near Brampton. In Northumberland, on the other hand, there are important coal deposits in the limestone group. The mapping of the Scremerston series is well advanced and the valuable Shilbottle Coal which occurs at a higher horizon is now being mapped. Much attention has been given to the correlation of the numerous limestone beds in the Alnwick and Berwick districts, as by this means the structure of the country, which is much obscured by drift, may ultimately be satisfactorily ascertained.

In Scotland the Carboniferous Limestone is one of the principal series containing resources of coal and iron ore and is hardly less important in this respect than the Coal Measures. The Limestone Coals or Edge Coals, as they are called in Midlothian, are being very carefully surveyed in Fife, the Lothians, Stirlingshire, Ayrshire and Lanarkshire, and revised maps on the six-inch scale are published or in preparation. Several important advances in our knowledge of this group have been made during the past season. In Ayrshire, for example, it has been proved that the conditions during the deposition of these strata indicate a gradually subsiding land surface, which, owing to differential movement, was subject to a certain amount of warping or distortion. In North West Ayrshire the Calciferous Sandstone epoch was marked by great volcanic activity; the lavas and ash beds of this period extend from Largs and Dalry by Eaglesham to Strathaven in Lanarkshire. To some extent these volcanic rocks rose above the sea level and were subjected to atmospheric weathering and erosion. On the east and south a land area consisting of Old Red Sandstone and Silurian rocks persisted till after the lower limestones were deposited. The gradual submergence of this land surface is marked by an overlap of the Carboniferous Limestone on the platform of older rocks. At the same time there is a marked unconformability and certain of the undermost members of the limestone group are absent in the neighbourhood of Sorn. Subsidence apparently was most rapid in Central Ayrshire, as the limestone series there is thickest and most complete. By a careful study of the groups present in each area and their thickness it has been possible to reconstruct the Lower Carboniferous shore lines and to indicate the amount of subsidence in different districts during the successive stages of Lower Carboniferous time.

The Carboniferous Limestone series encircles the Scottish coalfields and rises between them in broad anticlines in North Ayrshire and the Lothians. In the lower part of the Limestone group

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several beds of limestone occur and their identification in different parts of the country and their correlation with one another are difficult problems which have given rise to much discussion. None of these limestones has characters so perfectly marked and distinctive that they can be easily recognised, and the correlation has to be attempted partly by their lithological characters and partly by the nature of the beds associated with them. In forming conclusions regarding the geological structure, the thickness of stratigraphical groups, the boundaries between the Calciferous Sandstone and the Carboniferous Limestone, and the position reached in bores and sinkings, the identification of these limestones is often of considerable importance, though few valuable seams of coal, oil-shale or ironstone occur in or near this group of strata. Mr. Richey has arrived at certain conclusions regarding the correlation of the Lower Limestones of North Ayrshire and Renfrewshire, belonging respectively to the Ayrshire and Central Coalfields. Similarly the correlation of these limestones in the tract surrounding the Central Coalfield has been under discussion for several years and is fairly well agreed on. Mr. Dinham has now been able, with the help of certain bores recently put down near Bo'ness by Mr. Cadell, to correlate the limestones of West Fife with those of Stirling, Bannockburn and Bathgate. It will now be possible to extend the correlation into Central and Eastern Fife and to trace the characters and thickness of individual seams and the general variation of the groups across Scotland from the west coast to the east.

The general sequence in the Carboniferous Limestone series in Scotland has long been well established and is fairly uniform throughout its extension. It is a matter of considerable importance, however, to have recognisable datum lines of which the position is known exactly. The more widespread such index beds are the more valuable they become as enabling us to fix accurately the correlation of other strata by their relative position. Two such index beds have been proved by long practical experience to be especially useful, as they are very constantly present, their characters and their fossils are distinctive, and they occur among a group of strata where accurate localization is often much to be desired. One of these is the *Edmondia* bed which accompanies the Calmy or Jenny Pate Limestone. The other is the Johnstone Shell-bed which occurs well down in the Limestone Coals. During the past year fresh records of these two index beds have been obtained in districts where they were not previously known to occur; in this way their value is greatly increased. For example, if the cores of a boring supposed to pass through these horizons do not show any indication of the index bed it is very probable that the position is not accurately determined and further investigation is desirable. The Johnstone Shell-bed is known in Fife, the Central Coalfield and Ayrshire. It lies below the horizon of the Kilsyth Coking Coal, an especially valuable seam often searched for by

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boring, and, in cases of doubt, or where it is suspected that the bore has passed through a fault, the Johnstone Shell-bed may prove a decisive element in the evidence.

The Millstone Grit is not of importance in Britain as a source of coals, though yielding flagstones, fireclays and other useful minerals. In North Lancashire this series has been mapped over a considerable area around Bolton, Todmorden and Rochdale and the identification of its marine bands by their goniatite fauna has yielded interesting results. In the Whitehaven coalfield the Millstone Grit consists very largely of shales, and its upper limit still lacks definition. In Ayrshire the Millstone Grit consists mostly of lava flows and fireclay seams, one of the latter being the Ayrshire bauxitic clay, which is the most refractory fireclay mined in Britain. Some new outcrops of that group in Central Ayrshire have been mapped during 1923, but it is doubtful whether the bauxitic clay will prove of the same high quality as the deposits of this material in the neighbourhood of Saltcoats and Kilwinning.

In the Coal Measures much detailed work has been done, of which perhaps the revision of the Concealed Coalfield of Yorkshire and Nottinghamshire by Dr. Gibson and Mr. Wilson deserves special mention. Since the last edition of the memoir on this field was prepared there have been many new sinkings and bores, and a good deal of unpublished information on the structure of the field has been collected as the result of these explorations. In the Whitehaven coalfield the mapping is being pushed northwards to the margin of the exposed Coal Measures, where they sink below the Trias of the Carlisle area, but little definite information regarding the concealed coalfield is yet to hand.

In Central Ayrshire the lavas and red sandstones of supposed Permian age cover a considerable area in the centre of the coalfield and there must be large reserves of coal which as yet have not been worked. Mr. Bailey and his staff have been revising this ground and are able to give preliminary estimates of the depth at which the principal coals, such as the Ayr Hard, may be expected to occur. Little new information of special interest has been collected regarding the red measures of the Upper Carboniferous, Permian and Trias. Mr. Wilson furnishes some notes on the Magnesian Limestone and Permian breccias encountered in shafts and borings in Nottinghamshire.

The areas of other Mesozoic rocks surveyed during the year are mostly in the south and east of England. In the Marlborough Sheet the unconformability between the Gault and the Jurassic has received attention from Mr. Dewey and his staff, who have confirmed Bennett's observations that near Swindon the Gault rests on Kimmeridge Clay. In the Upper Cretaceous some notable sections have been examined in North Kent, and many fossils collected from chalk pits through opportunities kindly afforded by the Cement companies.

The Cainozoic rocks of the London Basin continue to occupy a

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large part of the time spent in the field by the London unit. Some of the new roads now being made near London furnish excellent and much desired sections through the basal beds of the Tertiaries and have been carefully measured and photographed. The large number of bores that are sunk every year in search of water, especially in the Chalk and Greensand, are a constant source of new information regarding the lithology and thickness of these groups and their capacity as water-bearing strata.

In Scotland, on the other hand, the rocks of Tertiary age are mainly volcanic. During 1923 it has proved possible to complete the mapping of the third of the three great volcanic foci of the Inner Hebrides. The Skye centre was mapped by Dr. Harker and his descriptions and maps were published in 1904. Mull has been completely surveyed and the maps and memoirs are now in the press. Mr. Bailey, Mr. Richey and Dr. Thomas have now finished the mapping of Ardnamurchan. This is a comparatively small volcanic centre, but it exhibits remarkable complexity of structure and repeats many of the distinctive features of Skye and Mull. In particular the circular structures known as ring dykes, screens and cone-sheets are present in great variety and the lithological types, though not identical with those of Mull, show a marked affinity with them in all essentials.

JOHN S. FLETT.

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II.—FIELD WORK

(A)—ENGLAND AND WALES

1. LONDON AND SOUTH-EASTERN DISTRICT

HENRY DEWEY, District Geologist.
H. G. DINES, A.R.S.M., A.M.Inst.C.E.
F. H. EDMUNDS, B.A.
W. N. EDWARDS, B.A.
} Geologists.

In the London District mapping in Sheet 257 (Romford) was continued and completed.

Mr. Dines examined the area around Brentwood, Laindon and Fobbing, while Mr. Edmunds completed that north of Brentwood and Billericay. After completing Sheet 257 Messrs. Dines and Edmunds moved to the Marlborough country, where they were joined by Mr. Edwards, who was temporarily transferred from the Yorkshire unit, to survey the Jurassic rocks around Calne and Wootton Bassett in order to complete the six-inch survey of Sheet 266 (Marlborough).

Considerable modifications have been made to the Romford map, the principal being the addition of the Claygate Beds, the mapping of which has revealed the structural features of the area as a series of gentle folds.

In the Marlborough district the dominant characteristics are: the overstep of the Gault across the Lower Greensand on to the Jurassic rocks; the pre-Cretaceous folding and faulting of the Jurassic rocks; the wide, gently folded outcrop of the basement beds of the Kimmeridge Clay; and the Coral Rag inliers. An interesting development of terrace gravels marking an abandoned course of the Bath Avon has been mapped by Mr. Edmunds.

During the year Mr. Dewey was engaged upon the preparation of two of the Special Reports on Mineral Resources, namely, Vol. I. Tungsten and Manganese Ores, 3rd edition, and Vol. XXVII. Copper Ores of Cornwall and Devon, both of which are now published. The following maps and memoirs were in preparation during the year:—Sheet 271 (Dartford) and Sheet 239 (Hertford) are both being colour-printed; the manuscripts of the memoirs are well advanced; Sheet 256 (North London) is in dry-proof state and the manuscript of the memoir in preparation; Sheet 318 (Brighton) and Sheet 333 (Worthing) are being colour-printed; the memoir by Mr. H. J. Osborne White is in proof.

Enquiries relating to water supply by both public companies and private persons have been numerous, over 200 having been answered during the year. Some interesting results of boring for water were recorded. The Upper Greensand has yielded important supplies at Burghclere and Inkpen, while the Lower Greensand at Rochester has supplied an abundance of good water. Several boreholes are in progress, as at Virginia Water, Thames

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Haven and elsewhere in Essex, in all of which the Lower Greensand lies at a depth of over 1,000 ft. from the surface. An abundant supply of artesian water was obtained from the Bagshot sands, at a depth of 850 ft., in the New Forest.

The excavations along the arterial roads in Kent have been under observation and have revealed some notable sections. At Swanscombe Hill the Lower Tertiary formations were cut open from the London Clay down to the Thanet Sand ; many fossils were obtained in the Blackheath and in the Woolwich Beds. This material is expected to yield important evidence as to deposition and correlation with similar beds elsewhere.

By permission of the Associated Portland Cement Manufacturers, Ltd., a magnificent series of fossils has been collected from the Gault and Chalk of North Kent and the Survey is also indebted to that Company for copies of analyses of materials used in the manufacture of their cement.

Marlborough Sheet

Marlborough Map. During the autumn Messrs. Dines, Edmunds and Edwards surveyed the Jurassic rocks in Sheet 266. These comprise the Cornbrash, Oxford Clay (including Kellaways Rock), Corallian, Kimmeridge Clay and Portland formations.

Cornbrash.—Two small inliers exposed by stream-erosion have been noted by Mr. Edmunds, one in Draycot Park, and the other about 400 yds. west of it, both one mile north of Sutton Benger (Sheet 265). In the former an old quarry about 4 ft. deep gives a few sections. In the latter there are good sections in the banks of a small stream flowing south, to the west of Upper Seagry.

Oxford Clay.—The outcrop of this formation presents two types of physiography—a hilly tract, and a low-lying flat tract. Mr. Edmunds considers the latter to be due to the River Avon, and on this tract he has mapped several large spreads of gravel. A sandy development probably referable to the Kellaways has been noted in Draycot Park. This sandy facies is notably developed at about 70 ft. from the junction of the Oxford Clay with the Cornbrash. Up the valley running north-north-west from Beacon Hill, Mr. Edmunds finds that the fossiliferous shales seen in excavations for the Great Western Railway near Christian Malford also occur in the churchyard of that village.

Mr. Edwards notes that the Oxford Clay to the west of Wootton Bassett gives rise to moderately hilly country. It calls for no special mention, except where exposures occur near the top. Here the fossils indicate a cap of Corallian age, and these beds will be considered under that heading.

Corallian.—This formation is divisible into three groups, (a) the Lower Calcareous Grit, (b) the Coral Rag and (c) the Upper Calcareous Grit.

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(*a*) *Lower Calcareous Grit.*—Mr. Edwards has found a narrow strip of these beds extending from Vastern Manor through Tockenham Wick to the Folly, north of Lyneham (Fig. 1). The big escarpment along this strip is usually capped by Coral Rag, though

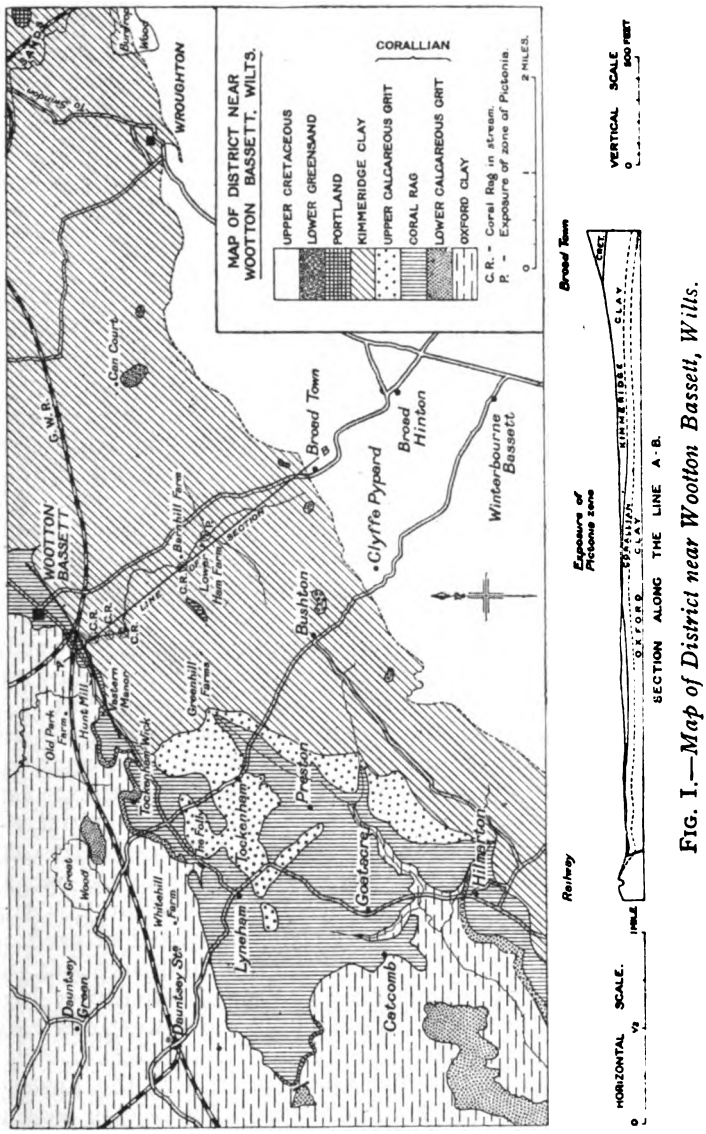

FIG. 1.—*Map of District near Wootton Bassett, Wilts.*

locally it consists entirely of the Grit, the Coral Rag then forming a very small and indefinite feature above.

In the outlier south-east of Great Wood, the grits appear to contain interbedded clays. Three pits in the area afford sections of from 8 to 10 ft. in the Lower Grit, which here consists of current-

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bedded sands, sometimes with thin clay seams. North of Lyneham they are separated from the overlying Rag by a thin bed of hard grey sandstone. In no case is there a section showing the base of the Grit. Near Vastern Manor and Lyneham the Lower Grit is believed to pass laterally into clay. In the railway-cuttings, half a mile west of Wootton Bassett Station, at least the top 20 ft. of the blue clay, mapped as Oxford Clay, which here underlies the Coral Rag, is shown by the fossils to be of Lower Corallian age. It contains numerous specimens of *Gryphaea* of Lower Corallian type, encrusted with *Serpula tricarinata* J. de C. Sow. and *Webbina sp.* The brickyard by Old Park Farm, mentioned by H. B. Woodward, has yielded a close-ribbed Cardioceratid which appears to indicate the Scarburgense Zone of the Argovian, a stage used by Buckman to comprise the beds in which *Cardioceras* occurs.[1]

The field relations suggest that the clays of this brickfield are at a lower horizon than the base of the Lower Grit, but it is a point that cannot be proved, owing to the lack of other exposures and the prevalence of minor folding in the area.

Beyond the western end of the Lower Calcareous Grit outcrop blue clay with ironstone and numerous fragments of *Gryphaea* found in the spoil from the reservoir at Whitehill Farm also suggests a lateral passage of the Lower Grits into clay. At this end of the outcrop the sandy facies seems to die out suddenly. Thus it appears that where the Lower Calcareous Grit is absent the base of the Coral Rag by no means corresponds with the true base of the Corallian.

In the south-west of the area mapped by Mr. Edwards the normal Lower Calcareous Grit is present south of Preston, in the valley which runs north-north-west from Hilmarton, but it is too thin to be mapped. In the escarpment farther west, six feet of sand was seen by Blake and Hudleston[2] in Catcomb quarry, now overgrown. It is probable that the Lower Calcareous Grit is present as a continuous, though thin, bed in this district.

Mr. Edmunds finds that the Lower Calcareous Grit extends north, under the Coral Rag from Hilmarton, dying out about half a mile north-north-west of Witcomb Farm. A good exposure, shewing about 12 ft. of grits, composed of sand, grey-black clay and a compact calcareous grey sandstone 2 ft. thick, occurs in the stream at Hilmarton. A small outcrop, a few feet thick only, has been mapped half a mile south-west of Goatacre. Here yellow sand occurs.

Mr. Dines remarks that the upper portion of the Lower Calcareous Grit is locally represented by a stiff grey clay containing fragmentary shells. It occurs between Mile Elm and Weaver's Bridge and passes laterally into a blue-grey sandy loam cemented locally into grey argillaceous pyritic sandstone. Lignite also occurs in the loam.

[1] 'Geology of Whitby and Scarborough' (*Mem. Geol. Surv.*), 1915, pp. 60, 87.
[2] *Quart. Journ. Geol. Soc.*, vol. xxxiii, 1877, p. 294.

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From excavations in the stiff clay and the grey sandy loam near Tossels Farm, Mr. Dines collected fossils that Dr. Kitchin and Mr. Pringle have identified as Corallian forms. They include : *Vertebriceras* cf. *dorsale* S. Buckman, *Cardioceras sp.*, *Peltoceras* ? *Exogyra nana* (J. Sow.), *Ostrea* (*Alectryonia*) *gregaria* J. Sow., *Pleuromya recurva* (Phill.), *Gryphaea sp.* [small forms], *Gryphaea sp.* [*G. dilatata* Auctt.], *Pecten sp.*, *Gervillia* ?, *Webbina sp.*

Stiff grey clay in the Lower Calcareous Grit occurs also at the small faulted outlier at Silverstreet ; it occupies the upper portion of the Grit on the downthrow side of the fault. This clay was previously classed as Coral Rag. A small quarry to the south of Reynolds Hill Farm shows about five feet of stiff grey clay with shell fragments resting on about ten feet of loose yellow sand with doggers. A seam of sandstone about 2½ ft. thick contains a few shells and lies at four feet below the junction with the clay.

At Westbrook, a quarry in the Lower Calcareous Grit, situated near the south-western extremity of the fault line, shows about 20 ft. of the Grit, which consists of coarse yellow uncemented sand containing comminuted shells. At the base a two-foot seam of blue-grey shelly sandstone underlies four feet of sandstone stained dark red and cemented into bands in which casts of shells are common. This was previously mapped as Lower Greensand, but there is little doubt that it should be included in the Lower Calcareous Grit.

Bowood is an almost flat area traversed by deeply cut and steep-sided valleys ; according to Mr. Dines the Lower Calcareous Grit occupies the flat ground, while the valleys are cut down well into the Oxford Clay, which serves to hold up the waters of Bowood lake.

It has been noted that the Lower Calcareous Grit occurs beneath the Coral Rag at Catcomb[1] a few miles to the north. Owing to the fact that the Grit is greatly attenuated in this locality it does not appear on the Old Series one-inch geological maps. It has, however, been traced by Mr. Dines from the western edge of Catcomb Wood around the boundary of the Coral Rag as far as the north-east corner of Melsome Wood, but it thins out and apparently disappears eastwards of these points. A small fault, probably caused by landslips, throws down the beds about 80 ft. to the west, and to this fault is due the outlier of the Grit between Godsall (Gotshill) Farm and Melsome Wood.

Faulting attributable to landslips on a large scale occurs on the west side of the area near Loxwell Farm. A fault affecting both the Jurassic and the Cretaceous rocks courses through Horse Copse in a direction south-west by west, while a second fault, nearly at right angles to the former, passes to the west of Spital Farm.

(*b*) *Coral Rag.*—Mr. Edwards has mapped beds of this age at

[1] Blake, J. F., and W. H. Hudleston. *Quart. Journ. Geol. Soc.*, vol. xxxiii, 1877, p. 294.

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and south-west of Wootton Bassett. Their junction with the underlying beds in most places is marked by a prominent escarpment. A small inlier of Coral Rag in the Kimmeridge Clay area has been mapped about one and a half miles south of Wootton Bassett. Exposures of Coral Rag were found at several points in the bed of the stream, recently deepened, above Hunt Mill, and as far south-east as Barnhill Farm, where Coral Rag is seen in the stream banks for some distance.

These exposures are important as indicating the presence of minor folds and the thinness of the covering of clay on the Coral Rag, as far south-east of Wootton Bassett as Barnhill Farm.

Small quarries in the Coral Rag are numerous. The new pit on the main road south of Tockenham Wick gives the best section. Here the Coral Rag, which has numerous partings of dark clay, is very fossiliferous, *Pseudodiadema versipora* Wright being abundant.

(*c*) *Upper Calcareous Grit.*—The thin beds to which this name is given show on the surface as reddish sandy loam. No good exposures occur. In a pond near Lyneham was seen two feet of reddish ferruginous sandy clay with thin layers of ironstone.

The revised mapping suggests that these beds are contemporaneous with some portion of the clay, mapped as Kimmeridge Clay, overlying the Coral Rag to the north-east. In this connection it should be noted that Salfeld[1] shows that at the Telford Road clay pit near Swindon the Kimmeridge Clay facies includes the two Corallian zones of *Perisphinctes decipiens* and *Ringsteadia pseudocordatus*.

Kimmeridge Clay.—A large area, forming on the whole flat ground, has been mapped by Mr. Edwards.

Near Lower Ham and Middle Ham Farms, between Wootton Bassett and Broad Town, deepening of the stream has exposed argillaceous and sandy limestone, in which the following fossils were found: *Ostrea deltoidea* forming shell-banks, *Pictonia sp. nov.*, *Pleurotomaria reticulata* (J. Sow.), *Astarte ovata* Smith, *Nucula menkei* F. A. Roem., *Opis* ?, and *Rhynchonella inconstans* (J. Sow.).

The presence of the zone of *Pictonia*, the lowest of the Kimmeridgian, is indicated more than half way across the Kimmeridge Clay outcrop, and the occurrence of the inlier of Coral Rag, previously mentioned, makes it appear that not more than half of the 300 ft. of the Kimmeridge Clay, estimated as occurring at Swindon, is present in this area.

Near Swindon the upper beds of the Kimmeridge Series, above the Virgatites Zone, are largely sandy, and were previously mapped as Lower Portland Beds.[2] They are not well exposed in this area.

Mr. Edmunds has mapped a small outlier of Kimmeridge Clay about a quarter of a mile south of the railway station at Calne.

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[1] *Quart. Journ. Geol. Soc.*, vol. lxix, 1913, pp. 423-430.

[2] Chatwin, C. P., and J. Pringle. 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, p. 162.

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Portland Beds.—A small area of Portland Beds has been mapped in the extreme east of Mr. Edwards's ground.

The recognition of the Kimmeridge age of all the beds below the top of the Swindon Clay shows that the Portland Beds of the Swindon district cover an area much smaller than that shown on the old one-inch map. The area in Mr. Edwards's ground is part of a small outlier of synclinal structure occupying the high ground between Swindon and the Coate reservoir, and detached from the large outlier of Swindon Hill.

Lower Greensand.—Mr. Edwards finds that until further work is done it is impossible to state definitely whether the Lower Greensand is overlapped by the Gault over much of this area, or is present everywhere as a very thin bed beneath that formation. Several small outliers of Lower Greensand occur. In Burderop Wood, south of Swindon, the Gault appears to rest on Kimmeridge Clay, and was so mapped, here and farther east, by Mr. F. J. Bennett.

Exposures are few, and hill-waste from the Chalk escarpment often obscures the relations of the Gault with the underlying rocks.

Structure of the Jurassic rocks.—The country dip is to the south-east and approximates to 1°, but the area is affected by minor folding with the same general direction of strike. This is well illustrated south of Wootton Bassett (Fig. 1), where the broad outcrop of Kimmeridge Clay would convey an impression of considerable thickness were it not for the inliers of Coral Rag that have been brought to the surface by these undulations.

The fault at Wootton Bassett seems to have originated in the breaking of the middle limb of a more or less monoclinal fold. Not enough evidence has yet been collected to prove the age of this folding, though it is believed to be earlier than the Gault of the district. There is an unconformity at the base of the Lower Greensand, for that formation rests on Purbeck beds at Swindon and on Corallian beds south of Calne, but it cannot be proved that the Lower Greensand is not involved in the folding. South of Calne an extensive overlap of the Lower Greensand by the Gault has been mapped by Jukes-Browne.

Prof. H. L. Hawkins[1] has pointed out that both the Upper Jurassic and the Lower Cretaceous rocks are affected by similar folding in the Vale of White Horse, farther east, and that the Gault overlaps the Kimmeridge Clay.

Mr. Dines observes that in the area that lies between Calne, Seend and Chippenham there is a marked overlap of the Cretaceous rocks upon the Jurassic, and calls attention to a pre-Cretaceous fault which passes in a north-easterly direction from Westbrook and dies out in the vicinity of Quemerford. In 1888 Jukes-Browne noted a similar and almost parallel fault north of Seend which disappears beneath the Lower Greensand at Rowde. Between these faults the Jurassic strata have been thrown upwards and have

[1] *Proc. Geol. Assoc.*, vol. xxxiv, 1923, p. 237.

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assumed a gentle easterly dip, while to the north-west of the Westbrook-Quemerford fault the general dip is more to the north of east. Around Spye Park and Bowood the Lower Greensand rests upon the Coral Rag ; the outlier at Laggus Farm lies upon a thin remnant of Kimmeridge Clay ; while, between the faults, from Rowde north-eastward to Quemerford, the Lower Greensand rests upon the Lower Calcareous Grit and at Quemerford it overlaps the Coral Rag and the Kimmeridge Clay.

Pleistocene and Recent.—Mr. Edmunds has mapped the alluvium along the portion of the Bath Avon and its tributaries that lies within the area of Sheet 266, and also some spreads of gravel along the main valley. It has been found that the Avon, while maintaining its general line of flow as a strike stream along the Oxford Clay, has made several minor deviations from its course.

The belt of alluvium is of variable width. In general the valley is broad and open, bounded on the east by the steep clay slopes beneath the scarp of the Lower Calcareous Grit, and on the west by the Oxford Clay hills. Here the alluvial belt is wide, being nearly a third of a mile between Christian Malford and Sutton Benger. This broad valley becomes narrower with steeper sides below Tytherton Kellaways, and also one mile north-west of Christian Malford. At these localities the alluvial belt attains only a quarter of its width farther up stream. South of Tytherton Kellaways the stream makes a hairpin bend towards Chippenham, there turning on itself again and resuming its original trend. At half a mile south-south-west of Pewsham Locks, on the Wilts. and Berks. Canal, Mr. Dines notes that the alluvium is only 75 yds. wide.

Gravels.—Spreads of gravel extend from Dauntsey and Somerford (in Sheet 252) to Tytherton Kellaways where they end abruptly against the River Marden and are not found again in the neighbourhood. Many sections show from 4 to 6 ft. of stratified, cream-coloured gravel, covered with 1 to 2 ft. of chocolate-coloured loam. The gravel is uniform in composition. It consists mainly of flat pebbles of sandstone and limestone and many water-worn shells of *Gryphaea* derived from the Jurassic rocks, with a small proportion of sub-angular flints, and an occasional pebble of ferruginous sandstone, probably from the Lower Greensand. The gravel at Christian Malford, as shewn in a pit at Malford Farm, has much finer constituents than that exposed in other pits and is of little economic value.

The various spreads, resting on the Oxford Clay, act as water reservoirs, and many shallow wells are sunk through them, particularly at Christian Malford and at Sutton Benger.

The largest spread occurs on the right bank of the river, opposite Christian Malford, extending from Sutton Benger (Sheet 265) to Sutton Lane Farm. Near the Wellesley Arms Inn at Sutton Benger it extends downwards from 190 ft. above O.D. in a gentle, generally unbroken slope, to the present alluvium.

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The village of Christian Malford, with the exception of the Church and rectory, stands almost wholly on gravel. This extends north for half a mile from the village, where it is separated by the Bourne stream from an original continuation running north-east by Dodford Farm.

A further large spread between Avon Mill and Tytherton Lucas is bisected by a stream running through East Tytherton. Smaller patches are found just north of West End, half a mile east of Lower Seagry, east of Somerford, and on the right bank of the stream opposite Kellaways Mill.

Diversions of the Avon.—The mapping of the gravels has brought out several points of interest. Half a mile north-west of Christian Malford the Avon now flows south-westwards from Seagry Mill. From Dauntsey to this point its valley is broad and open, but here becomes narrow, with comparatively steep slopes; the alluvium reaches to the foot of the slope on either side. The gravels of Christian Malford are about 15 ft. above the present level of the alluvium, and reach a height of about 190 ft. above O.D. along Dodford Lane. Between these gravels and the present stream is a clay hill, reaching a height of 212 ft. The stream has been diverted from its original course through Christian Malford, and now flows through a narrow deep valley, which widens again into a broad open valley south of the Chippenham-Christian Malford road.

This spread of gravel is seen to be separated from the present river, and, with much of the other gravel mapped, forms a distinct terrace, a feature somewhat obscured in several of the other spreads. It is proposed to call this terrace the Christian Malford Terrace, to differentiate it from the gravels of the present river, the Flood-plain Terrace, which occur slightly above the alluvium.

A second diversion of the main stream has occurred south of Christian Malford. A small patch of gravel occurs north of West End. As previously stated, the church at Christian Malford stands on a clay hill. The stream now flows to the west of this hill, whereas the gravel spread is to the south-east.

A further and somewhat similar case occurs at Kellaways Mill, where a slight hill, with blue clay on the top, separates the large gravel spread extending from Avon Farm to Tytherton Lucas from the present stream.

Romford Sheet

Woolwich and Reading Beds.—Mr. Dines notes that in a pond to the south of Lorkins Farm, about a mile north of Orsett, yellow sand of the Woolwich beds appears in a small inlier, overlain by greenish clay with pebbles, belonging to the Basement Bed of the London Clay. Although the beds are ill-exposed the junction between the London Clay and the Woolwich Beds has been traced also in the vicinity of Stanford-le-Hope.

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London Clay.—A brickpit excavated in the lower part of the London Clay at Sticking Hill shows about 5 or 6 ft. of brown sandy clay with faint signs of horizontal bedding. On drying, the loamy clay breaks into thin laminæ. The beds resemble the Claygate Beds, though the bedding is not so conspicuous.

Claygate Beds.—These beds have been traced by Mr. Dines along the southern slopes of the Brentwood outlier from Great Warley Street eastwards to Herongate, Botneyhill and Little Burstead, and also around the Laindon Hills, where they maintain a fairly uniform thickness of 25 to 30 ft. They are well exposed in a brickpit in the outlier near Vange Hall (in Sheet 258), where a typical section shows 28 ft. of bedded buff sands and lilac clays.[1] They have also been mapped in the vicinity of Temple Wood, north-east of Stock (in Sheet 241), and occur as an outlier partly covered by boulder clay at Downham in Sheet 258.

Mr. Edmunds has mapped the Claygate Beds which underlie the outliers of Bagshot Sand in the neighbourhoods of Kelvedon Hatch—Brentwood—Ingrave ; Fryerning—Ingatestone ; Billericay ; Stock ; and also small outliers uncapped by Bagshot Beds at Mountnessing ; at half a mile west of Great Burstead ; and at Outwood Farm.

Good sections at Brentwood, Shenfield and Ingatestone show the Claygate Beds to be more homogeneous than those at Claygate. The beds vary in thickness from about 40 ft. at Stondon Massey (in Sheet 240) and 25 ft. at Shenfield, to 5 ft. at Ingatestone. The last thickness is shown in an exposure in the railway cutting to the east of the railway staiton.

The best exposure is at Shenfield, where the beds, 25 ft. in thickness, are exposed, and consist of buff silt, laminated and false-bedded, with lenticles of fine sand up to 2 ft. in thickness. Evidence of contemporaneous erosion is well seen in the western face of the pit. Here a bed of carbonaceous material about 4 in. thick is found.

The outcrop of the Claygate Beds has been mapped continuously from Billericay eastwards through the woods half a mile east of Outwood Farm. In the railway cutting in the woods a layer of septaria[2] varying in height from two ft. to about ten ft. above the base of the cutting occurs in the London Clay. The beds here show very gentle flexuring. Above this layer the Claygate Beds, containing numerous boxstones, are developed.

Bagshot Beds.—A small outlier of Bagshot Beds capping Botneyhill has been recorded by Mr. Dines. The re-survey of the Laindon Hills has rather reduced the size of the outlier shown on the Old Series one-inch maps. Near West Lee Hall a pit exposes the Bagshot Beds where compact fine-grained yellow sands show very faint lines of false-bedding.

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[1] Wooldridge, S. W., and H. C. Berdinner. *Proc. Geol. Assoc.*, vol. xxxiii, 1922, p. 322.

[2] 'The Geology of London' (*Mem. Geol. Surv.*), vol. i, 1889, p. 260.

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Mr. Edmunds finds that these beds cover a larger area than that shown on the Old Series one-inch map. In the Brentwood district false-bedded Bagshot sands occur at about 270 ft. above O.D. in the neighbourhood of Brentwood Brick Works. Bagshot sands, which also occur around Brockley Grove, are shown in a sandpit in Brockley Grove Corpse, half a mile south of Shenfield station, and a small outlier has been noted about half a mile east of this outcrop, near Mill's Farm. The detailed mapping of these beds shows that the Brentwood hills have the structure of a gentle anticline, with a northerly axis. South of Stock, and east of Billericay, there is a large extent of Bagshot sands. From Mill Hill, half a mile south of Billericay, Bagshot sands extend for half a mile east, crossing Jackson Lane. To the east of Billericay the sands are well exposed in the railway cutting a quarter of a mile north-west of Outwood Farm. One mile east-north-east of Billericay a large portion of Forty Acre Plantation consists of this formation, which is well exposed in many trenches dug during the war. This outlier is almost continuous with that extending from Stock to about 200 yds. south of Great Bishop Wood.

A gentle flexuring of the beds appears to have occurred throughout the district, but no evidence of the Billericay Fault, assumed by Prof. Boswell,[1] has been found at the surface, for the base of the Bagshot sands everywhere maintains a fairly constant level.

Bagshot Pebble Bed.—The only occurrence of this bed *in situ* was noted at South Weald, at the section described by H. B. Woodward.[2] By permission of Mr. J. D. Faulkner, of Baldock, Messrs. Dines and Edmunds made borings from the base of the pit in South Weald Park, and also cleared the face of the section. It was found that the description given by Woodward is substantially correct. The upper gravel, however, classed as Glacial by him, by Messrs. Dines and Edmunds is correlated with the Warley Beds, which they disassociate from the Bagshot Beds.

Warley Beds.—The re-survey of the pebbly gravel at Warley, previously classed as Bagshot Pebble Beds, has shown that this gravel rests unconformably upon the Tertiary strata. About ten ft. of it is exposed in a pit at Holden's Wood. It closely resembles the upper portion of the section described at Langtons, South Weald Park[3], which has been ascribed to the Glacial period.

In this pit Messrs. Dines and Edmunds sunk a borehole ten ft. in Bagshot Sand below the base of the gravel without encountering any trace of pebbles and without entering the Claygate Beds. Further spreads, beneath which the thickness of Bagshot Beds varies, occur on the north of Thorndon Park and south-east of Great Warley Street. At the latter locality the gravel crosses the Bagshot-Claygate boundary ; while half a mile east of Emery Farm

[1] *Quart. Journ. Geol. Soc.*, vol. lxxi, 1916, p. 536.

[2] 'The Geology of London' (*Mem. Geol. Surv.*), vol. i, 1889, p. 273; and H. W. Monckton and R. S. Herries, *Proc. Geol. Assoc.*, vol. xi, 1889, p. 19.

[3] 'The Geology of London' (*Mem. Geol. Surv.*), vol. i, 1889, p. 273.

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a pit shows five ft. of pebbly gravel similar to that at Holden's Wood, resting on the London Clay. The dissimilarity between the gravel of Holden's Wood and the true Bagshot Pebble Bed in South Weald Park has been noted by Messrs. H. W. Monckton and R. S. Herries[1].

The gravel spreads previously mapped as Bagshot Pebble Beds at Temple Wood, Stock, Dudbrook, Navestock Side, Mill Green, Fryerning, and Billericay, provide no evidence for this classification, and as indicated by Messrs. Monckton and Herries (*op. cit.*), appear to belong to the Warley type.

Glacial Gravel.—Mr. Dines observes that spreads of gravel occur at Warley and Childerditch, and are composed largely of flint pebbles, but contain a comparatively larger proportion and variety of erratics than the gravels exposed in Holden's Wood. They appear to rest at a level only slightly below that of the Warley gravels and to the south-east of Warley Barracks actually come in contact with them. Gravel of glacial age has been mapped both at Ramsden Heath and near the pumping station half a mile to the north ; also near Boards Farm about a mile north of West Hanningfield.

Mr. Edmunds has mapped patches of Glacial gravel at Claypitshill Wood, one mile east of Billericay, at Fryerning Wood, a quarter of a mile north of Grange Farm, Fryerning (Sheet 240), at half a mile west of Imphy Hall, Stock, and at Thrift Wood, about one mile east of Brentwood. The deposits at Mountnessing, previously mapped as of unknown age, have been separated into Glacial gravel and Boulder Clay. At Fryerning Wood a pit has been opened in the gravel, giving a section showing a maximum of ten ft. of unstratified gravel. Many boulders up to two ft. in diameter occur ; boulders up to four ft. in diameter, which probably came from this pit, may be seen in the neighbourhood of Ingatestone and Fryerning. All gradations from these boulders to fine sand occur. Many types of rocks are met with, including rhyolite, Triassic sandstone, sarsen, flint and chert.

Boulder Clay.—Several small spreads of Chalky Boulder Clay have been mapped by Mr. Dines between East Horndon and Botneyhill, and farther west at Childerditch church there is another small occurrence. Much of the intervening ground appears to be covered with *remanié* drift.

Mr. Edmunds has mapped patches of Boulder Clay at a mile north-east of Shenfield, between Trueloves House and Ingatestone, at half a mile east of Billericay, at 100 yds. from Ninge's Farm, Burstead, and around Norsey Wood, Billericay. The deposits, previously shown as of unknown age, at Mountnessing, at half a mile east of Ingatestone Brick Works, and at a quarter of a mile north of Ramsden Bellhouse, are shown to be Boulder Clay.

River Gravels.—Spreads of river gravels have been mapped by Mr. Edmunds in the Crouch valley, to the south-west of Ramsden

[1] *Proc. Geol. Assoc.*, vol. xi, 1889, p. 21.

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Bellhouse. A wide spread occurs between Crays Hall and Ramsden Park, shewing three ft. of stratified gravel, at a height of about 85 ft. above O.D.

At Slicesgate a record of seven ft. of gravel was made by Whitaker[1]. No indication of this was visible to Mr. Edmunds, but he noted, 200 yds. to the south-west of Slicesgate, at about 109 ft. above O.D. a newly dug pit, shewing four ft. of soil, resembling weathered London Clay resting on one foot of stratified, pockety gravel on brown clay.

A small spread, 200 yds. east of Ingatestone Hall, has been mapped in the valley of the Wid.

The undifferentiated gravels at Fobbing (Sheet 258) have been separated into their respective terraces.

HENRY DEWEY.

[1] 'Water Supply of Essex' (*Mem. Geol. Surv.*), 1916, p. 95.

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2. MIDLAND DISTRICT

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R. W. POCOCK, B.Sc. }
T. H. WHITEHEAD, M.Sc., A.R.C.Sc. } Geologists.
T. ROBERTSON, B.Sc. }

During the past season work has been concentrated upon the western part of the Wolverhampton Sheet (153). Mr. Pocock has progressed westward across the Trias from Tong and Albrighton to Shifnal and Stirchley, and Mr. Whitehead has surveyed an area of Triassic rocks near Weston-under-Lizard and a tract comprising Pre-Cambrian, Cambrian, Carboniferous and Triassic rocks around Lilleshall and Priorslee and near Wellington. Mr. Robertson has surveyed the Trias between Pattingham and the Severn, and has begun the revision of the Broseley portion of the Coalbrookdale Coalfield.

Pre-Cambrian.—The Uriconian rocks of Lilleshall Hill have been surveyed by Mr. Whitehead. They consist mainly of purple and green 'halleflintas'; but volcanic breccias with a 'halleflinta-like' ground-mass occur north and east of the monument. About 30 yds. south of that point the 'halleflintas' are marked by nearly straight parallel bands, which dip west-north-west at an angle considerably higher than the average of 40° noted by Callaway[1]. A line of junction of a bed of breccia with the 'halleflinta' runs parallel to this banding, which appears therefore to be an original structure. At the south end of the hill the Uriconian rocks disappear from view west of the church, but are again exposed in the road about 80 yds. south-west of the Old Hall.

Cambrian.—The characteristic glauconitic and micaceous Comley (Hollybush) Sandstones are well exposed in the road at Lilleshall from the Old Hall to the church. They dip south-eastwards at 27° to 37°; but west of the church, near the fault that separates them from the Uriconian rocks, the dip rises to 50°. Numerous fragments turned up by the plough in the fields immediately at the western foot of Lilleshall Hill indicate that the Comley Sandstones crop out on this side also. No exposures of the rock *in situ* were, however, found west of the hill.

Silurian.—West of the Severn Mr. Robertson has examined the Linley Brook inlier of Downtonian rocks, and finds that the reading of that section given by Roberts and Randall[2] is in the main correct, but the lowest beds exposed are those associated with the Ludlow Bone-bed, which crops out along the stream-channel south-

[1] 'The Precambrian Rocks of Shropshire,' *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, p. 646.
[2] 'On the Upper Silurian Passage-beds at Linley, Salop,' *Quart. Journ. Geol. Soc.*, vol. xix, 1863, pp. 229–232.

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east of Linley Hall. Dr. L. D. Stamp[1] has recently suggested that this inference may be drawn from Roberts and Randall's account. Upwards the passage by way of the Temeside Beds into the red mudstones of the Ledbury Passage-Beds is clearly exposed, the Downton and Temeside Bone-beds being both present.

Carboniferous: Coal Measures.—Southwards from the old quarries in the Carboniferous Limestone at Lilleshall the base of the Limestone, and that of the cream and buff sandstones that overlie it (the 'Millstone Grit' of the Old Series map, Sheet 61 N.E.), were observed by Mr. Whitehead to converge upon one another. At a point 300 yds. south-west of the church, fragments of Comley Sandstone were found on the surface within a few yards of an exposure of these sandstones, and no trace of the Carboniferous Limestone remained. It is concluded, therefore, that the so-called Millstone Grit is unconformable to the Carboniferous Limestone, oversteps it in a southerly direction, and finally comes to rest upon the Cambrian. This view receives some support from the relations between the Carboniferous Limestone and the 'Millstone Grit' observed in the eastern limestone quarry by Mr. Dixon.

In the area at the northern end of the Coalbrookdale Coalfield examined by Mr. Whitehead the lower part of the Upper Coal Measures consists mainly of mottled clays of Etruria Marl type, with breccias in which the fragments are as a rule quite angular, and of which the matrix is frequently very ferruginous. It is found, however, that shaft-sections in which the highest workable seams (the Chance Pennystone, Fungus Coal, etc.) are absent owing to the overstep of the Upper Coal Measures (*i.e.*, the Symon Fault), sometimes show beds of grey clay, shale, and sandstone between the highest workable seam remaining and the lowest bed of red clay. These grey clays, etc., cannot be matched amongst the measures below the highest seams in sections where these last are present. It seems legitimate to conclude, therefore, that the grey beds in question constitute, where present, the lowest strata of the Upper Coal Measures, and that the lowest red clay (the 'calamincar' of some sections) is thus not a reliable index of the base of that subdivision[2].

The clays that resemble the Etruria Marl are succeeded by red, mottled, and grey clays and marls, in which, at Snedshill, a blue-grey Spirorbis limestone was found. These clays and marls alternate with beds of sandstone, some of which resemble those of the Newcastle or Halesowen Group. It is difficult, however, to recognise a well-defined Newcastle Group.

About 600 ft. above the base of the Upper Coal Measures the beds become predominantly red in colour and present all the characters of the Keele Group. In the stream-course north-west of Muxton Mr. Whitehead found red marls with lavender and

[1] *Geol. Mag.*, 1923, p. 369.

[2] *Cf.* W. J. Clarke, 'The Unconformity in the Coal-Measures of the Shropshire Coalfields,' *Quart. Journ. Geol. Soc.*, vol. lvii, 1901, p. 87.

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purple sandstones and cornstone, near to, and on the downthrow side of, the Boundary Fault. These beds, which dip to the north-west, are clearly not Bunter, and should probably be assigned to the Keele Group.

The Keele Beds are succeeded on the eastern side of the coal-field from near Lilleshall southward by a group including calcareous dull-red sandstones with lenticles of calcareous conglomerate. These are referable to the Enville Beds.

West of Shifnal Mr. Pocock has mapped the surface geology of part of the eastern side of the Coalbrookdale Coalfield. He finds that the Enville Beds form a belt of calcareous red sandstones and conglomerates interbedded with marls. They extend from Knowlbank and Haughton on the north, through the Wyke, to Kemberton and Suttonhill on the south.

South of Linley Brook Mr. Robertson finds that the well-known Spirorbis limestone of the Sulphur Coal Group rests almost directly on the denuded surface of the 'Red Downtonian' rocks. In some places the Main Sulphur Coal is present a few feet below it; in others it appears to be absent. The Brock Hall Coal is fairly persistent at a distance of 20 ft. or so above the limestone. The total thickness of grey measures (the Sulphur Coal Group) at Nordley is not more than about 150 ft. North of Linley Brook the Sweet Coal Group emerges from beneath the Sulphur Coal Group and rapidly thickens northwards towards Caughley and Broseley. It rests unconformably on the Downtonian, and farther north on the Aymestry rocks. Coarse gritty sandstones characterize the lower part of the group.

In the southern portion of the field, around Apley Park, the Keele and Enville groups are poorly developed and not well exposed. At the base, red marls appear to predominate and form the lower part of the scarp on the left bank of the Severn, north-west of Apley Park. Higher in the sequence calcareous marl-conglomerates, interbedded irregularly with reddish calcareous sandstones, are exposed. These are overlain unconformably by the Lower Mottled Sandstone of the Bunter, the junction being exposed in a railway cutting south of Apley Park, where a thickness of 4 to 5 ft. of Lower Mottled Sandstone is seen resting on an eroded surface of alternating dark-red sandstones and marls. At Apley the total thickness of the Keele and Enville groups does not exceed 200 ft. This attenuation is probably due to thinning, accentuated by pre-Triassic erosion.

Trias.—Mr. Whitehead finds that, south-west of Lilleshall, the Lower Mottled Sandstone directly overlies the Keele Beds on the downthrow side of the Boundary Fault near Muxton. About three quarters of a mile to the south-west it lies against the Boundary Fault. In character it here approaches the 'millet seed' type noted by Mr. Dixon in the Newport District.[1]

[1] 'Summary of Progress' for 1919 (*Mem. Geol. Surv.*), 1920, p. 16.

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Between Lilleshall and Hadley the Trias is largely obscured by drift, and its relations to the outcrop of Keele Beds at Preston-on-the-Weald-Moors are problematical.[1]

In the area surveyed by Mr. Pocock near Shifnal the Lower Mottled Sandstone does not appear to be very thick. It is well exposed at Brimstree Hill, about a mile south of Shifnal, where it exhibits strongly marked current bedding, and at many points along the deeply incised valley of Wesley Brook south of Shifnal, as at Evelith Mill.

The Pebble Beds form high ground east of Shifnal, extending from Lizard Hill on the north to Brimstree and Havenhills on the south. The general dip is south-eastwards at from 2° to 5°. Their junction with the Lower Mottled Sandstone is well seen at Brimstree Hill, where the coarse pebbly sandstone lies on the denuded edge of the underlying soft false-bedded sandstone. At Upton and in the railway cutting near the Coalport Works (Shifnal) the junction is irregular, the Pebble Beds here resting on a very uneven surface of the Lower Mottled Sandstone.

The Upper Mottled Sandstone is of the usual soft red laminated type and is exposed at many points from Tong Forge on the north to Ryton on the south. It is dug for moulding sand at Hole Farm near Cosford and sent to Horsehay and Coalbrookdale.

The base of the Keuper Sandstone can be studied at Tong Forge, where the soft red Upper Mottled Sandstone is overlain by a pebbly coarse calcareous sandstone with marl-pellets. At the base of this sandstone there are, in places, lenticular masses of large pebbles (up to 6 inches in length) of quartzite, Carboniferous limestone and chert, and other rocks. The quartzite pebbles have all the appearance of those found in the Bunter Pebble Beds. At Tong Castle the calcareous sandstone with marl-pellets can again be seen resting on the Upper Mottled Sandstone, and at Cosford the junction is well exposed both in the railway cutting and at Cosford Pool.

Farther east, near Donington, Albrighton, and Tong, the higher beds of the Keuper Sandstone take on a more clayey facies and pass up into the Keuper Marl.

The area mapped by Mr. Robertson lies only a few miles north of the classical Bridgnorth district, and affords good exposures of the three subdivisions of the Bunter. The valleys of the Severn and Worfe are cut deeply into the Lower and Upper Mottled Sandstones respectively. In the case of the Severn, Apley Terrace shows the calcareous basal conglomerate or breccia of the Pebble Beds lying in strong unconformity on the highly current-bedded bright-red Lower Mottled Sandstone, which in this neighbourhood cannot be more than 300 ft. in thickness and appears to thin out northwards from Bridgnorth. The basal breccia of the Pebble Beds also appears to thin out northwards, being about 30 ft. thick east of Bridgnorth, whilst at Stockton it seems to be less than 10 ft. Within

[1] 'Summary of Progress' for 1919 (*Mem. Geol. Surv.*), 1920, p. 8.

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the area surveyed it is a somewhat subangular conglomerate rather than a breccia, the majority of the pebbles being fairly well rounded, whilst sharply angular fragments are not common. Though the higher strata of the Pebble Beds are not very well exposed, they can be seen to consist of alternating sandstones and incoherent pebbly sandstones of the usual type. The Upper Mottled Sandstone is, on the whole, finer in grain and darker in colour than the Lower Mottled Sandstone in this neighbourhood.

The basement-beds of the Keuper Sandstone form a scarp along the left bank of the Worfe. Here and there, as at Beckbury and in Badger Dingle, calcareous marl-conglomerates are developed at the base ; but in most places they do not appear, and the transition from Bunter to Keuper is marked merely by a gradual change in colour from red to brown and by the appearance of flaggy micaceous sandstones, in some places replaced by a marly band. Coarse-grained pebbly and non-pebbly sandstones are exposed along Nun or Stratford Brook, east of which the Upper Mottled Sandstone is brought up again by faulting. A small strip of Keuper Marl lies along the downthrow side of this fault just west of Patshull.

Igneous Intrusions.—Mr. Pocock finds that the post-Carboniferous intrusive basalt that underlies the Carboniferous Limestone at the Hatch and Little Wenlock (Sheet 152) overlies the Limestone in Lydebrook Dingle and reaches a still higher horizon at the Horsehay and Doseley quarries. At the latter the basalt shows remarkable columnar jointing throughout.

Glacial and Post-Glacial.—In the area between Lilleshall and Wellington surveyed by Mr. Whitehead the Glacial deposits fall fairly well into the three groups recognised by Mr. Dixon around Newport.[1]

The unbedded clayey drift extends over the rising ground of the coalfield and has been traced to heights of well over 500 ft. above sea-level. The high-level sands and gravels do not usually extend above 450 ft. in the area surveyed, the chief exception being a somewhat ill-defined patch at Mosseygreen (south-west of Oakengates), which lies at over 500 ft. The sands that form a continuous belt extending from Ketley by way of Hadley and Wombridge to Oakengates fall mainly within the category of high-level sands and gravels ; but their lower geographical limit is ill defined, as they pass down to the north below the 300-ft. contour-line, and cannot be separated from the sands and gravels of the low ground, which would fall into Mr. Dixon's third or low-level group. From Ketley north-westward to Wellington the main deposit of sand lies below 300 ft., the higher ground being occupied by boulder-clay. About Ketley and Hadley the sands and boulder-clay seem to be somewhat intimately interbedded. South of the Humbers, and between that hamlet and Honington, much of the ground is occupied by a stiff grey clay, weathering brown or purplish, and containing few

[1] 'Summary of Progress' for 1919 (*Mem. Geol. Surv.*), 1920, p. 17.

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or no stones. Though not visibly laminated where observed in this area, this clay may perhaps be correlated with the laminated clays found by Mr. Dixon farther north within the area of his 300-ft lake.[1] The feature that possibly indicates the shore-line of this lake can be traced at intervals along the north-western margin of the coalfield. It always marks off, somewhat sharply, the low-lying area of little relief from the rising well-featured ground. Near Ketley and Wellington the supposed shore-line takes the form of a rather steep bank, or of two banks with a bench or shelf between them, the banks and bench being cut in the drifts.

Mr. Pocock reports that there is very little drift over the Keuper Marl area east of Tong and Donington ; but on the lower ground to the west, in Tong Park and round Ruckley and Stanton, sands and gravels cover large areas, but are nowhere more than a few feet thick. In these gravels pebbles of granite are plentiful, and large isolated boulders of the same rock are common, especially near Tong.

Patches of boulder-clay associated with sand and gravel occur at Hatton Grange and Atchley Manor. At Hatton there is said to be upwards of 10 ft. of boulder-clay on sand.

The Pebble Beds outcrop near Shifnal is for the most part free from drift, but small patches of clayey gravel are found on Aston Mount (Aston Coppice). On the low ground to the west of the Pebble Beds outcrop there are flat spreads of a loamy clay with few stones, underlain in places by rather coarse sand and gravel, as seen at various points along the valley of Wesley Brook, south of Shifnal. Shifnal itself is situated on a broad area of sand that appears to be continuous with the clay-covered sand to the south.

Mr. Pocock has noted the occurrence of traces of yellowish-brown boulder-clay on the summit of the Wrekin at a height of 1,335 ft. above O.D. The clay yielded various pebbles, some strongly striated, including granite, microgranite, rhyolite, quartzite, grits, and rocks suggesting on the whole a Lake District or a Southern Scottish, rather than a Welsh origin. Traces of the boulder-clay occur at other points along the Wrekin ridge.

In Mr. Robertson's area a tract of predominantly drift-free country around Pattingham and Rudge gives place westward to the valley of Nun Brook. In this there is a flat clay-covered area around Patshull ; but Rudge Heath (Sheet 167) is covered by a sheet of sand and gravel, near the western side of which rises a sinuous ridge of gravel, very esker-like in form. The Nun Brook channel south of Patshull is deeply incised. Still larger deposits of sand and gravel occur in the Worfe valley between Ryton and Worfield. On the east side the valley is bounded by a scarp capped with Keuper sandstone, whilst on the west lies a fairly flat stretch of ground, mainly covered with clayey deposits. This rises to a gravel-bank along the west side of the river-course and suggests by its topography that it is the flood-plain of heavy Late-Glacial drain-

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 20.

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age from the north, flowing by way of Mad Brook and the present Worfe channel. At a later stage more intensive erosion along the base of the Keuper scarp, by a smaller volume of water, produced the present Worfe valley, through which the river now meanders in still smaller volume.

In the Severn valley at Apley two well-defined flood-plains are to be seen, 10 ft. and 20 ft. respectively above the present level of the stream. Higher gravel-terraces are developed at levels of 60 and 100 ft. above the river-level. In the country immediately to the south-west there are several patches of boulder-clay just over 300 ft. above sea-level. A few spreads of fairly coarse gravel at about the same elevation in the valleys of Linley and Dean Brooks resemble morainic rather than fluvial deposits.

A clear case of river-capture is to be seen in the extreme south-west corner of Sheet 153, where Linley Brook, profiting by the rejuvenation of the Severn in the Ironbridge–Bridgnorth reach, has cut back at right-angles to the main south-easterly line of drainage, and captured the head-waters of two tributaries of Mor Brook, at Nordley Common and at the Smithies. In the latter case an old terrace on the left bank of Linley Brook above the point of capture is graded with the channel of the Mor Brook tributary.

T. C. CANTRILL.

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3. YORKSHIRE DISTRICT

C. N. BROMEHEAD, B.A.	District Geologist.
G. V. WILSON, B.Sc.	Senior Geologist.
D. A. WRAY, M.Sc.	Geologists.
J. V. STEPHENS, B.Sc., B.ENG.	
W. N. EDWARDS, B.A.	

During the past year Mr. Wilson has been engaged in collecting information and revising the memoir on the 'Concealed Coalfield of Yorkshire, Derby and Notts.', under the general supervision of Dr. Gibson; an account of his work appears below. Mr. Edwards joined the staff in the autumn, but on completion of his training was temporarily removed to the Marlborough area (p. 31). The other members have been engaged in mapping the Huddersfield Sheet (77), begining on the western margin, in contact with the work of the Lancashire unit. Mr. Wray had previously been attached to the latter and carried on his work there eastwards in the southern part of the Huddersfield Sheet; his experience and knowledge of the Millstone Grit sequence proved invaluable, and a large proportion of the following account is his work. The northern part of the Sheet was assigned to Mr. Stephens, while Mr. Bromehead surveyed the middle strip on either side of the Calder valley. The sequence of the beds determined in the north, middle and south respectively is given, from left to right, in the accompanying figure (Fig. 2).

In Crimsworth Dean, the main valley about Hebden Bridge, and in the valley west of Cragg, beds below the main Kinderscout Grit are exposed; on the original geological map (Sheet 88 N.W.) they were called 'Yoredale Rocks,' but neither in the lithology nor the palæontology is there any marked change at the base of that grit; it may prove advisable to extend the Millstone Grit Series downwards to include these lower beds, provided that a suitable base can be found in the area to the west. The remainder of the ground surveyed, with the exception of a small faulted basin of Lower Coal Measures mapped by Mr. Wray immediately to the south of Stainland, is occupied by the Millstone Grit Series in the accepted sense, the escarpment of the Lower Coal Measures that lies on the east of Halifax not having yet been reached.

Much of the ground consists of peat-covered moorlands, divided into two groups by the valley of the Calder, which is, in this part of its course, a dip-stream; they are subdivided by the tributaries, the Crimsworth and Luddenden brooks on the north, the Cragg brook, the Ryburn, the Black brook and the Colne on the south. The moors reach heights of 1,450 ft. on the north and 1,550 at Blackstone Edge, falling eastward to about 900; they are of economic importance as the gathering grounds for several large water-supply schemes, while the valleys are occupied by mills originally dependent upon water power.

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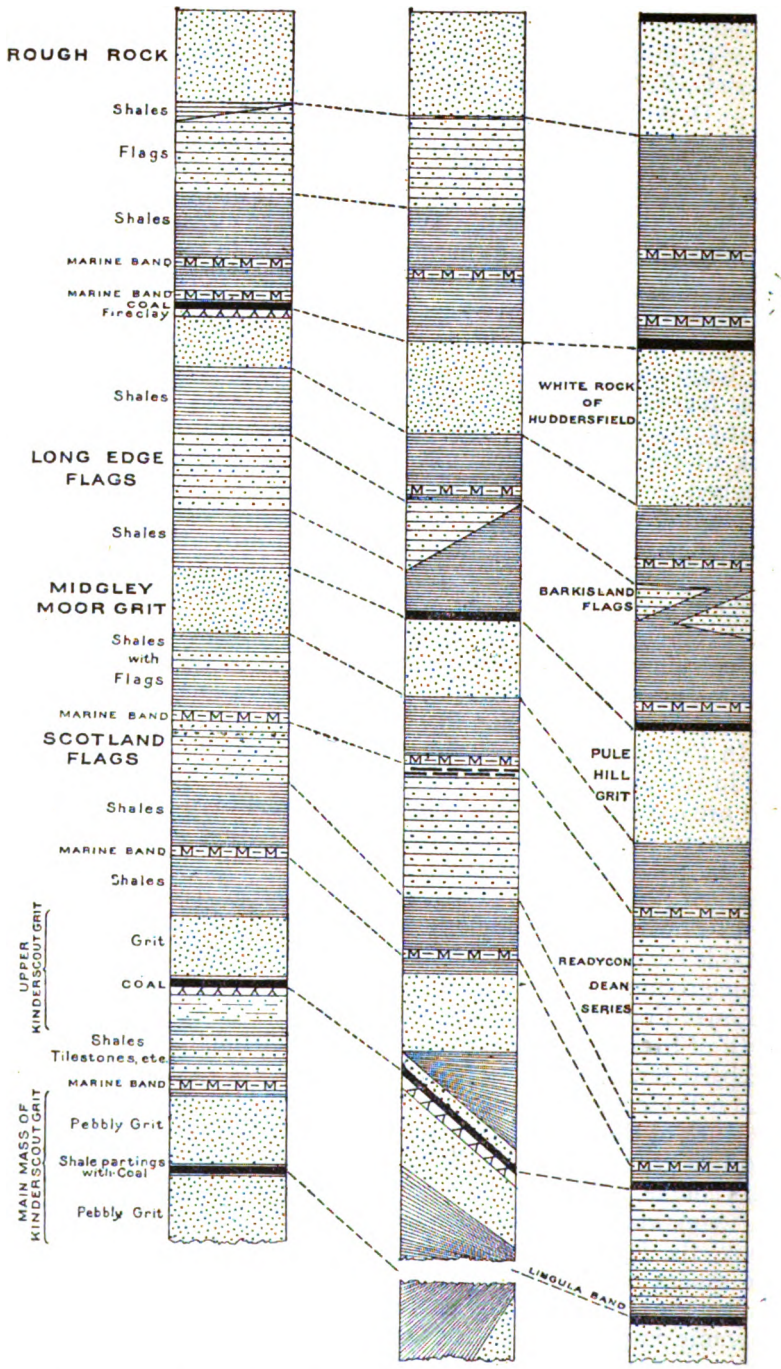

FIG. 2.—*Vertical Sections in the Millstone Grits of West Yorkshire.*

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The Kinderscout Grits.—The base of the Kinderscout Grit is a coarse and massive conglomerate usually resting on sandy shales; throughout the area it makes a strong feature and can readily be traced. In the southern part it forms a bold line of crags at Millstone Edge, surrounding the Castleshaw inlier of sub-Kinderscout shales and sandstones: a small periclinal uplift brings up the basement beds of the grit again immediately to the north at Ragstone, on Denshaw Moor. Between Millstone Edge and Pule Hill, west of Marsden, the whole succession of the Kinderscout Grit Series is well exposed both in a road-cutting (now being extended) and in several stream sections. It is here seen to consist of four principal grits separated by shales and mudstones; the three lowest beds are coarse and massive, but the uppermost is more flaggy and underlies a fireclay and coal, which persist as far north as Blackstone Edge. The shales underlying this uppermost member also contain a thin coal and fireclay, the coal being frequently split into two beds. About 6 ft. above the coal is a thin band crowded with *Lingula*. This horizon has also been recognised on the eastern slopes of Blackstone Edge and on Rishworth Moors; in the Green Withens valley this band contains abundant impressions of *Pterinopecten papyraceus* (J. Sow.) but no goniatites.

Farther north the lower Kinderscout grit forms Turley Holes Moor, where a coal has been detected at one or two localities, but a system of faults trending west-north-west to east-south-east from Stoodley Pike to Cragg and onwards brings in the upper grit to form Erringden and Bell House Moors. The lower bed crops out again and forms bold cliffs overlooking the Calder, Hebden and Crimsworth valleys, but disappears beneath the valley bottom, partly on account of the dip and partly through faulting, three-quarters of a mile below Hebden Bridge. Above the main grit the beds are very variable; on the southern flank of the Calder valley and on either side of Cragg Vale a series of shales is found, about 300 ft. thick, in which no marine band has been detected, though farther north Mr. Stephens finds one in this position containing *Glyphioceras reticulatum* (Phill.); on the northern side of the valley west of Midgley two small groups of flags have been mapped out, as they form shelves on which the farm houses are built.

North and west of Luddenden Foot the upper Kinderscout grit is a well-defined stratum, the coal-seam with seat-earth below and the Lingula bed above serving as an index. Mr. Stephens finds the grit above this break well developed, with only a small thickness of sandstone and flags below, while on either side of the Calder between Mytholmroyd and Luddenden Foot the grits above and below the coal are about equally developed, the combined thickness at Hathershelf Scout being 200 ft. From the neighbourhood of Luddenden Foot eastwards an important break develops; the lower leaf is a massive grit with the coal near the top, well seen in

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the railway cutting at Luddenden Foot station and disappearing beneath the river just above Dixon Scar. At that point some 75 ft. of shale intervene between it and the upper leaf, which consists mainly of flaggy sandstone with a coarse gritty base ; it attains a thickness of about 100 ft. and has been largely quarried at Dixon Scar and cut into along the canal bank near Sowerby Bridge.

The Middle Grits.—Above the uppermost bed of the Kinderscout is a series of shales and mudstones containing two marine bands in the upper of which a distinctive and well-recognisable mutation of *Glyphioceras reticulatum* is abundant ; the appearance of this fossil has been taken to indicate the base of the Middle Grits. One or both of the marine bands have been detected at a number of localities, from Pule Hill on the south through Buckstones Moss, Rishworth Moor and Triangle to the west and south flanks of Midgley Moor and several exposures in the Luddenden valley. Above these shales comes a variable series of sandstones, tilestones and ganister beds, which has already been termed the Readycon Dean Series,[1] owing to their extensive development at that locality. While they attain a thickness of about 300 ft. in this district, they rapidly thin away when traced eastwards, and to the north of Scammonden, in the Booth Dean and Deanhead valleys, are represented by a thin bed of flagstones. South of Manshead Moor a thin coal caps this series. In the Calder valley the flaggy beds are about 100 ft. thick, the lower part being economically valuable ; they are extensively worked for paving stones, etc., at the Scotland Quarries near Midgley. Farther north the thickness decreases somewhat.

They are succeeded by shales, towards the base of which is a marine band with a later mutation of *G. reticulatum*, and these in turn by a coarse grit traceable with little change throughout the district. It is conspicuous in forming prominent wall-like escarpments not unlike the Kinderscout Grit and Rough Rock, for both of which it has frequently been mistaken. It caps Manshead Moor, the northern end of Rishworth Moor, Waystone Edge and Buckstones Moor and also forms a prominent outlier on Pule Hill. Farther north it occupies the surface of Blackwood Common and the greater part of Midgley and Wadsworth Moors ; it is seen in the eastern part of the Sowerby Bridge railway cutting and disappears between that town and Copley. On the top of this grit Mr. Wray finds a thin coal and a fireclay, which has been seen at Load Clough, near Luddenden, but has not been detected farther north ; a little higher a marine band has been noticed by Mr. Wray only. The succeeding shales contain lenticles of flags and sandstones, well developed around Barkisland, the lower slopes of Stainland Moor, Long Edge Moor and on the slope to the east of Luddenden village, but not traceable around Sowerby Bridge.

A well-marked marine horizon intervenes between them and the

[1] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 50.

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succeeding beds, which consist of flaggy grit and sandstone to the north and east of Barkisland, but of a massive sandstone to the south, usually known as the 'White Rock' of Huddersfield. A prominent fireclay, and not infrequently a coal, known to the south as the Upper Meltham Coal, overlie this sandstone. Throughout the entire district a marine band, characterised by *Gastrioceras cancellatum*[1] lies in the shaly mudstones a short distance above this coal. The same marine horizon occurring in the same position above the Holcombe Brook Coal and Grit in the adjoining portion of Lancashire strongly suggests a correlation of the Holcombe Brook and Upper Meltham coals, and also of the White Rock of Huddersfield with the Holcombe Brook Grit. This grit or sandstone occupies the surface on Warley and Mixenden Moors and forms a shelf on which Warley Town is built. It appears as an inlier in the upper part of the Hebble valley near Wheatley.

The Rough Rock.—In the southern part of the area a thick series of shales intervenes between the White Rock of Huddersfield and the Rough Rock, the uppermost member of the Millstone Grit Series. Towards the north the lowest part of the Rough Rock becomes flaggy and is worked for flagstones on Greetland Moor, around Mount Tabor and in the scarp above the Hebble between Wheatley and Mixenden. The greater part of Halifax is built on the dip slope of the Rough Rock, which extends westward to Highroad Well Moor.

Lower Coal Measures.—A thin coal with a conspicuous underclay rests directly on the Rough Rock wherever the mapping has reached that horizon, and is known to have a wide range; the overlying shales contain a prominent marine band; three thin coals, the Soft Bed, Middle Bed and Hard Bed, occur above this. In the inlier of Lower Coal Measures near Stainland the Hard Bed has its usual marine roof and is comparable in every way with the Bullion Coal of East Lancashire. In the district between Halifax and Huddersfield the most remarkable feature of these measures is the poor development or absence of important sandstones, such as occur at this horizon in East Lancashire and South Yorkshire.

Structure.—In striking contrast with the western slopes of the Pennines, described in last year's Summary[2], the broad tectonic structure of the area is comparatively simple. On the whole the beds have a gentle easterly dip, while with a few marked exceptions there is no conspicuous faulting. The more complicated structures occur on the axis of the Pennines at Denshaw Moor and around Cragg, while a highly faulted syncline of Lower Coal Measures occurs to the south of Stainland. In the former area, additional evidence has been obtained to show that the 'anticlinal'

[1] Bisat, W. S., 'Gastrioceras cancellatum (sp. nov.) at Meanwood, Leeds,' *Trans. Leeds Geol. Assoc.*, 1923, p. 47.

[2] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, pp. 45–50.

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fault, to which Professor Hull[1] ascribed great tectonic importance, has a relatively minor effect on the geological structure of the Central Pennine area. As in the country to the north (described in last year's Summary, p. 46), there is a line of continuous fractures extending in a N.N.W.–S.S.E. direction close to the main axis of uplift, but their combined displacement is relatively small. They probably represent accommodating structures accompanying considerable monoclinal folding in a N.N.W.-S.S.E. direction. In brief, folding rather than faulting has played the dominant role. Other faults trending in a N.N.W.-S.S.E. direction have been met with on Soyland Moors and in the Ripponden valley.

As in the adjoining part of Lancashire, east-and-west fractures of considerable importance occur which materially affect the lie of the rocks. The most important of these extends from the southern end of Blackstone Edge across Rishworth Moors to Ringstone Edge, the exact position of which has been located during the construction of the Green Withens and Ringstone Edge reservoir embankments. This east-and-west fault, together with a parallel one to the north on Ringstone Edge Moor, have clearly been displaced by later movements along a prominent N.N.E.-S.S.W. fault at Ringstone Edge. East of Ringstone Edge the pair of faults continue for a considerable distance in an easterly direction, and to the immediate south of Stainland let in a trough of Lower Coal Measures between the Millstone Grits cropping both to the north and south of that area. Another nearly east-and-west fault of considerable size passes through Wainstalls and Illingworth; its effect on the Rough Rock scarp at the latter can be seen from a great distance. A broad shatter-belt extends from Todmorden and Stoodley Pike south-eastwards towards Ripponden; the structure around Cragg, where the sub-Kinderscout beds are brought up in several little inliers, is exceedingly complicated.

Pleistocene.—Glacial drift is entirely absent from these Pennine uplands, but in the Calder valley the well-known 'Mytholmroyd moraine' has been mapped: the bulk of the material forming it is of local origin, but many far-travelled boulders have been recorded; one igneous rock was obtained during the survey from a small temporary excavation, but there was no further opportunity of collecting specimens from an actual section; a little similar material occurs near Brearley. The gritstone moors are usually covered with an undisturbed mass of 'head' or weathered and kaolinised grit-debris, and in the higher part with a layer of peat mainly composed of cotton grass. Worked flints have not infrequently been met with on uncovering the peat, and in some parts the stumps of birch trees are common.

Acknowledgments.—Our best thanks are due to Mr. W. S. Bisat for his kindness in placing at our disposal his intimate knowledge

[1] Hull, E., 'The Geology of the Burnley Coalfield' (*Mem. Geol. Surv.*), 1875, p. 40.

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of the marine fossils ; to Messrs. T. Matthews & Co. for sections of borings near Huddersfield, and to the Engineers of the Bradford and of the Wakefield Waterworks.

C. N. BROMEHEAD.

CONCEALED YORKS–NOTTS COALFIELD

Mr. Wilson has been engaged in bringing up to date the available information concerning the Concealed Coalfield of Yorkshire and Nottinghamshire. The results and conclusions arrived at are shortly to be published in a new edition of the Geological Survey memoir on that area. In these circumstances only a few points, which are mainly of scientific interest, are discussed below.

Thorne Sinking.—The general section of the post-Carboniferous rocks in No. 1 Shaft is as follows: Bunter Sandstones to 915 ft. 8 in.; Upper Permian Marls (with numerous bands of gypsum and anhydrite near the base) to 1,023 ft. 11 in.; Upper Magnesian Limestone to 1,128 ft. 6 in.; Middle Marls to 1,256 ft.; Lower Magnesian Limestone to 1,504 ft. 6 in.; Basal Marls or Marl Slates 2 ft. 2 in. thick to 1,506 ft. 8 in.; at which depth Coal Measures were entered.

The Marl Slates yielded *Lingula credneri, Fenestella,* and a few almost perfect specimens of fish remains which are not yet identified.

Harworth Sinking.—The section of the strata passed through in No. 1 Shaft to the Barnsley Bed is as follows: Bunter Sandstones to 353 ft. 4 in.; Upper Permian Marls to 390 ft. 6 in.; Upper Magnesian Limestone to 431 ft. 10 in.; Middle Marls to 512 ft. 10 in.; Lower Magnesian Limestone to 698 ft. 4 in.; Basal Marls or Marl Slates to 720 ft. 8 in.; at which depth Coal Measures were entered.

The Mansfield Marine Bed, which consisted of 16 ft. 6 in. of dark bind above 1 ft. 6 in. of black limy cank, with green oil along the joint faces, occurred at a depth of 2,115 ft.; the Abdy Coal at 2,433 ft. 2 in.; and the Barnsley or Top Hard Coal at 2,787 ft. 4 in.

In both shafts an interesting bed of breccia was met about four feet below the Upper Magnesian Limestone. The bed is 6 ft. 6 in. thick and is very similar in appearance to the breccia which occurs at the base of the Permian system in South Nottinghamshire, and which extends northwards towards Worksop. The upper breccia is unknown in any of the other borings and sinkings in the area, though in the bore at Budby a bed of rather coarse grit occurs about the same distance below the upper Magnesian Limestone.

The rock is rather loose in texture, and greenish in colour when first met with, but turns red on exposure to the atmosphere. The enclosed pebbles are mainly subangular in form, and of all sizes up to 4 in. in length. They consist essentially of felsites, rhyolites and other granitic types of igneous rock, together with various fels-

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pathic grits and greywackes, and red and purple mudstones. From their general appearance it seems most probable that they have been derived from an area of pre-Cambrian rocks of Uriconian and Charnian types.

Budby Bore is situated in Sherwood Forest about 100 yds. west of the junction of the road from Edwinstowe, with the main Ollerton–Worksop road. The total depth of the bore is 986 ft. and the general section of the strata is as follows: Bunter Sandstones to 286 ft.; Upper Permian Marls to 304 ft. 6 in.; Upper Magnesian Limestone 2 ft. 10 in. to 307 ft. 4 in.; Middle Marls to 502 ft. 6 in.; Lower Magnesian Limestone to 690 ft.; Marl Slates 13 ft. 6 in. to 703 ft. 6 in.; and Basal Breccia 2 ft. to 705 ft. 6 in.; at which depth Coal Measures were entered.

The presence of the Upper Magnesian Limestone in this bore is of interest since it is the most southerly known occurrence. At Clipstone Colliery, 4 miles to the south-west, the Upper Limestone is absent, though the position at which it might have been expected to occur can be fairly accurately determined from the lithology of the associated strata. The 200 feet of Middle Marls which intervene between the Upper and Lower Magnesian Limestones at Budby consist mainly of red and blue marls above, and red and grey mottled sandstones below. The latter contain pockets of marl and the individual sand grains often show beautiful desert rounding. At Mansfield the beds which occur immediately below the Bunter and Conglomerate and overlie the Middle Marls are considered to be of Triassic age, and are known under the name of Lower Mottled Sandstone. The Marl Slates at Budby have yielded *Lingula credneri*, and a well preserved plant which has been determined by Dr. Kidston as *Ullmannia bronni*; a species common in the copper-bearing deposits of the continental Permian.

The 1st or Top Marine Bed, which occurs at a depth of 1,191 ft., and 326 ft. above the Mansfield Marine Bed at Boughton bore, was met with at 834 ft. at Budby.

In the first edition of the memoir[1] it was stated that although the post-Carboniferous deposits showed no evidence of the easterly extensions of the Don system of faulting and the Brimington Anticline, the possible continuations of these important disturbances should not be overlooked. Recent mining developments have shown this warning to have been completely justified.

W. GIBSON.

[1] 'The Concealed Coalfield of Yorkshire and Nottinghamshire' (*Mem. Geol. Surv.*), 1913, pp. 39, 40.

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4. LANCASHIRE DISTRICT

Headquarters: Manchester

W. B. WRIGHT, M.I.M.E.	District Geologist.
R. L. SHERLOCK, D.Sc., A.R.C.Sc.	Senior Geologist.
W. LLOYD, B.Sc.	Geologists.
L. H. TONKS, M.Sc.	
R. C. B. JONES, M.C., M.Sc.	

In Lancashire the mapping on the six-inch scale of Sheet 76 has been continued and is now almost complete. The use of goniatites for purposes of correlation has been developed, and has been found of great service. Unfortunately it is undesirable to give an account of this work, except in the most general terms, pending the publication by Mr. W. S. Bisat of his monograph on the Yorkshire succession, as most of the species are still undescribed.

The district surveyed during the past season embraces the type-area of the Haslingden Flags, and much information has been gleaned regarding the rapid lateral variation which affects these beds. Their relation to the eroding base of the Rough Rock has also been noted. A marine band between the Upper and Lower Flags has been found to have great constancy.

Examination of bore cores has been carried on concurrently with the field work. A conclusion of considerable scientific and economic importance has been reached regarding the lateral variation of the Millstone Grit Series, and will be dealt with in an appendix.

Millstone Grit.—Mr. Wright continued mapping in the area between Bolton and Darwen. The main point of interest emerging from this work is its bearing on the westward thickening of the Millstone Grit Series and the basal members of the Lower Coal Measures.

A peculiarly fine development of the old 'Third Grit' and of the beds above it has been found well exposed north of Ramsbottom. The four known marine bands of this series, each with its characteristic goniatite, all appear and render exact what would otherwise, owing to lateral variation, be a very unsatisfactory correlation. Underneath the uppermost of these bands is a bed of some economic importance, known locally as the 'Ironstone.' It is a ganister rock of variable thickness and is found to make a highly resistant and valuable road metal. It dies out westwards (*see* p. 63), but can be traced a long way east, where, however, its character varies somewhat.

Immediately below this last-mentioned bed is a remarkable series, about 30 ft. thick, of banded siliceous ironstones with shale partings. Comparison with sections both east and west shows it to be a phase of what elsewhere is ordinary mudstone.

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In the Blackburn and Haslingden area Dr. Sherlock attained some important results in the correlation of the grit series.

The belt of rocks with high dips, referred to in last year's 'Summary of Progress,' extends from Great Harwood through Rishton and Blackburn. The brickyard at Royshaw, north of Blackburn, shows an excellent section of the Haslingden Flags and Holcombe Brook Series. The grit crags exposed at the back of Blackburn Park belong to the Third Grit, and not to the Rough Rock, as formerly supposed. The First Grit crops close to the main entrance at the southern end of the park, and close to the position of the Ganister Coal on the published map. Consequently a strip of country about half a mile wide, extending through the town, is underlain by Millstone Grit instead of Coal Measures.

Millstone Grit forms the high moorland country south of Accrington. The area is separated from the coalfield by a great curving north-east fault, and from the Darwen coalfield on the west by an equally important south-east fault. Except in the neighbourhood of faults the grits are flat-lying, and around Haslingden the Rough Rock and Haslingden Flags form two striking terraces separated by a steep slope.

The Haslingden Flags (the Second Grit) pass readily into mud-flagstones. At Hutch Bank, west of Haslingden, the workable flagstone is fully 100 ft. in thickness, and the top lies about 125 ft. below the base of the Rough Rock (First Grit) and a few feet below a marine band. The flags thin westwards, while northwards of Haslingden Grane a new flag band becomes mappable above the marine band and about 50 ft. below the Rough Rock. The upper flags develop rapidly westwards and at Pickup Bank are about 50 ft. thick, the top being here only about 25 ft. below the Rough Rock; and a second set of flags of about the same thickness comes in some 60 ft. below the higher one. The lower flags are probably the representatives of those at Hutch Bank.

East of Haslingden there are three bands of flag, the highest member consisting of a few feet of valueless rock situated about 50 ft. below the Rough Rock. The middle is represented by a mass of about 125 ft. of rock with a shaly parting, and the lowest, about 275 ft. below the Rough Rock, is very thin. Northwards the highest flags disappear, as does also the lower leaf of the middle flags, but the lowest of the three thickens rapidly, and at the north end of the town has become about 100 ft. thick, while the middle member has declined to some 50 ft.

The Haslingden Flags appear to have been laid down in the delta of a slow-flowing river, the sand being deposited as flag and the clay dropped as a flocculent mass of mudstone. As the delta grew, sandstone and mudstone replaced one another laterally.

Farther eastward from the Bolton and Blackburn areas just referred to, it has been found that the belt of country between Burnley and Bury dealt with by Mr. Tonks has been productive of some interesting results regarding the stratigraphy of the

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Millstone Grit; a vertical section for the eastern half of the map is given on page 50 in the 'Summary of Progress' for 1922. Much new information has come to hand during the past year. To the west the beds from the Third Grit to the Rough Rock show a great increase in thickness. This new information has been invaluable in mapping, for the beds chiefly concerned are badly obscured by faulting and by a thick drift cover. In addition, two new marine horizons have been discovered above the Third Grit. The evidence at present available suggests that during the deposition of these beds marine waters lay to the west and south-west.

The Lower Haslingden Flags appear to attain a maximum development along the Rossendale valley. In the quarries east of Horncliffe they are over 100 ft. thick, and most of this seems to be workable stone. This development thins southward and to the north. For example, in the south the main mass splits into several beds by interdigitation and replacement with sandy shale and grey mudstone. The beds become thinner and die out, and along the line of Cheesden Brook one small bed of flagstone, 6 ft. thick, is the sole representative of the Lower Haslingden Flags.

The Upper Flags do not contain so great a thickness of workable stone. They have been extensively worked on the southern side of Rossendale, *e.g.*, Cragg quarry, etc. On the northern side of the valley above Newchurch they are represented by a few feet of shaly flagstone. This increases in thickness and improves in quality northwards. The change can be traced up the Crawshaw Booth and Waterfoot valleys, and seems to take place *pari passu* with the northward thinning of the lower flagstone. These variations chiefly affect the amount of workable stone at each horizon. In general they are due to lateral replacement of sandstone by sandy shale and mudstone.

The Upper and Lower Flagstones horizons contain beds of fine hard, compact, grey and brown sandstone. This, locally known as 'lonky,' is highly esteemed as a sett rock. It is often extensively mined. Many of the old quarries have been worked well back from the escarpment, making it necessary to remove a heavy overburden of shale, etc. Frequently the top of the Upper Flags is only separated by a few feet of shale from the base of the Rough Rock. In such cases the Rough Rock was removed in the overburden and tipped as useless. The thickness of the overburden speedily increased the cost of working, and quarrying operations gradually ceased. If the Rough Rock is crushed, however, it makes good clean and coarse sand, and this has led to the reopening of some of the old flag quarries.

The stone used in the Rawtenstall Corporation Housing Scheme was the Lower Haslingden Flags. This has also revived the quarrying industry locally.

A small lamellibranch is found in the grey mudstone which succeeds the Upper Haslingden Flags. This mudstone is about

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four feet thick. The shell contained in it has been found at this horizon over a wide area.[1]

The Rough Rock and Upper Haslingden Flags are separated by dark, slightly sandy, mudstone. This has been seen to vary in thickness between one and twenty-five feet. It is considered that this variation in thickness is partly due to the transgression of the Rough Rock across underlying measures. The base of the Rough Rock is very coarse and pebbly. In some of the large quarry sections the plane at the base is uneven, and cuts across the beds below.

Over most of the area coarse grit extends from the Sand Rock Mine to the base of the fireclay of the Six Inch Mine, but south of Knowl Moor these strata show interesting variations. The following shaft sections form a convenient summary of the changes :—

Bamford Closes Pit.	*Close Barn Colliery.*	*Smethurst Hall Fireclay Pit.*
Six Inch Mine.	Six Inch Mine, 9 in.	Six Inch Mine, 1 ft.
Fireclay.	Fireclay, 12 ft.	Fireclay, 4 ft.
Rock, 15 ft.	Rock, 5 ft.	Shale, 15 ft.
Black Shale, 6 ft.	Black Shale, 12 ft.	Sand Rock Mine, 2 ft.
Sand Rock Mine, 2 ft.	Sand Rock Mine, 2 ft. 5 in.	

The presence of a shale roof to the Sand Rock Mine has led in the past to confusion between this coal and the Six Inch Mine. Marine forms were said[2] to occur in the roof of the Sand Rock, but the roof of that coal is formed by strata which represent fresh-water swamp conditions rather than marine conditions. The marine forms are found two or three feet above the Six Inch Mine, and this marine band is followed by 50 ft. of blue shaly mudstone. There is, therefore, a lithological as well as a faunal difference in the strata above the two coals.

In this district the Sand Rock (locally known as the Three Quarters Mine) has an average thickness of about 2 ft. 3 in. It is an excellent steam coal and has been worked in many small collieries, most of which are now abandoned. In many cases these pits supplied local mills direct, especially those mills which were isolated from railway or canal.

The fireclay of the Six Inch Mine is from 4 to 12 ft. thick, and north-east of Bury is mined for brick making.

The area surveyed by Mr. Lloyd around Rochdale and Bacup shows only the higher members of the Millstone Grit Series. These occupy the Whitworth valley from Healey to Shawforth and make a wide spread over the moors to the west, broken on Brandwood Moor and Rooley Moor by restricted areas of Lower Coal Measures brought in by north-west faults. The effect of these faults, most of which throw down north-east, is to compensate the general dip to the

[1] For this and much other information we are indebted to Mr. J. Spencer, F.G.S., of Accrington.

[2] Binney, E. W., *Trans. Geol. Soc., Manchester*, vol. i, 1841, p. 73.

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south of the southern limb of the Rossendale anticline, and repeat the upper beds of Millstone Grit as far south as Norden.

Upwards of 400 ft. of strata occur between the base of the Lower Haslingden Flags and the Rough Rock on the south side of the Irwell valley at Stacksteads, probably representing a maximum development of the Haslingden Flag phase. The marine band overlying the Lower Flags is exposed in Brandwood quarry and several other localities around Facit, where the Upper Flags attain a thickness of 75 to 100 ft., and are extensively quarried. The working of 'lonkey' bands is the main object of present quarrying; these bands here vary in thickness up to 10 ft. and the stone makes good setts. Workable flagstone occurs in places to within several feet of the base of the Rough Rock.

Both Upper and Lower Flags decrease in thickness and quality to the south and are of little economic importance in the Norden valley.

The Rough Rock, coarse and pebbly in the top part, and frequently less coarse in the lower part, has an extensive outcrop around Whitworth and Facit. Its repetition by faults on the flanks of the Whitworth valley, and wide spread over the moors to the west, has given rise to the extensive working of the Sand Rock Mine, which here varies in thickness from 1 ft. to 2 ft. 4 in.

It is observed that there exists a belt of minimum thickness of Rough Rock, corresponding approximately with the crest of the Rossendale Anticline.

The western margin of Sheet 76 having been found to present many difficulties of interpretation, surveying was commenced by Mr. Jones in the moorlands west and south of Belmont, in Sheet 75, with the view of assisting in the elucidation of these difficulties. Up to the present no differentiation of the grits in this area had been carried out, and several interesting variations in the succession, as compared with areas to the east, have become apparent. As it will be some considerable time before Sheet 75 is published the following local details are given now.

Two miles west of Belmont typical Third Grit has been mapped, together with the three characteristic overlying marine bands. These latter occur in 40 ft. of soft blue mudstone, the sandy ironstone beds and 'Ironstone' ganister, which extend this succession to 100 ft. in the Irwell valley north of Ramsbottom, being entirely absent.

The Brooksbottoms Sandstone, here some 50 ft. thick, forms the plateau of Hordern Pasture and Spitler Edge, and dipping gently south is terminated in very much faulted ground, immediately west of Belmont.

The Holcombe Brook Coal, clearly identified by its overlying marine band with *Gastrioceras cancellatum* Bisat, is 2 ft. thick, and rests directly on a thin sandstone. The coal has been worked along its outcrop in a small faulted area at Dean Brook.

The Lower Haslingden Flags are represented by 100 ft. of mud-

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stones and only 8 ft. of ' lonky ', which is itself entirely replaced by the mudstones to the south-west, as has been proved in a bore put down near Horwich.

The Haslingden Flag marine band is well exposed in the stream section at Shore, and is followed by 100 ft. of mudstones before the base of the Upper Flags is reached. The latter, consisting of alternating beds of flags and mudstones, here attain a maximum thickness of 250 ft. They have been quarried to some extent to the east of Winter Hill.

The Rough Rock caps Counting Hill and is developed on the southern slopes of Winter Hill. Below the Sand Rock Coal it consists of coarse white grit about 30 ft. thick, while the upper ' leaf ' above this coal is soft shaly sandstone. The whole of the Rough Rock is 60 ft. thick, showing only a slight thinning as compared with the areas to the immediate east.

Lower Coal Measures.—In comparison with the Millstone Grit Series below, the Lower Coal Measures show only a moderate amount of lateral variation. The general succession in the Accrington area, given in last year's ' Summary of Progress,' applies with modifications to the country around Blackburn, now dealt with by Dr. Sherlock. At Rishton the Crutchman Sandstone and the Bookleaf Shales beneath have ceased to be separable, and are replaced by a succession of sandstones and shales. On Oswaldtwistle Moor, south of Oswaldtwistle, the Crutchman changes its character from a flagstone to a sandstone, which is sometimes very massive, and then resembles a millstone grit without pebbles.

On the south side of Blackburn, at Grimshaw Park, large quarries show about 60 ft. of sandstone underneath a coal and a fireclay. The coal has been worked and has always been regarded as the Lower Mountain Mine, but it is probable that the seam is really the Pasture Mine, with the Crutchman Sandstone below. This correlation has important results, for it suggests that the Lower and Upper Mountain Mines and the Cannel Coal remain unworked over an area of about a square mile, bounded by faults.

In the Darwen coalfield the Crutchman Sandstone is well developed and known as the Darwen Flags. It has been extensively worked. The Hey Fold Sandstone, above it, is represented at Accrington, mainly by Shales.

The Old Lawrence Rock (Hambledon Scout of Accrington) persists into the Blackburn area and underlies the Workhouse on the south side of the town. The Accrington mudstone occurs beneath it and is worked for bricks at the back of Queen's Park. The north-west fault, which bounds the Darwen coalfield towards the east, appears to have a throw of about 550 ft. at Pickup Bank, bringing the mudstones below the Haslingden Flags against the Lower Mountain Mine. The curved north-east fault which cuts off the Accrington coalfield towards the south is visible in Cattle Higher Plantation, south of Accrington. The throw here is esti-

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mated at about 550 ft. and brings the base of the Rough Rock against the Bookleaf Shales. The section shows a reversed throw, but the exposure is not deep enough to prove that the fault is really a reversed one.

Between Darwen and Pickup Bank the coalfield is divided by numerous faults, many of them proved in workings to be of considerable throw.

In the Darwen coalfield, in addition to the Upper and Lower Mountain Mines, the Little Coal (Cannel Coal), the Bin Mine (Upper Foot), and the Ten-Inch Mine (Lower Foot) are worked, but only to a small extent and primarily for the fireclays beneath.

The recognition by Mr. Wright farther south in the Bolton area of the development of a thick and massive grit a few feet below the base of the Woodhead Hill Rock has led to important modifications in mapping, as much of this rock was hitherto mistaken for Rough Rock.

To the east Mr. Tonks has found that the sandy strata at the horizon of the Woodhead Hill Rock are extensively variable in character and thickness. North-east of Waterfoot, for example, the strata which represent the main mass of the rock elsewhere are poor shaly sandstones and sandy shales. In places a lower 'leaf' of the rock, some 20 ft. thick, is developed at the expense of the underlying shale. Again, north of Bury the Bassy Mine rests on about 20 ft. of sandy shale and flaggy sandstone. This, in turn, rests on a fairly coarse, massive felspathic sandstone about 25 ft. thick. These beds appear to be attenuated representatives of the beds at this horizon to the south-west.

Above the Bassy Mine occurs a *Carbonicola* band which is constant over a wide area. Its recognition has been a great help towards accurate mapping. Near Bury the section is:—

		Ft.	in.
	Dark and blue shaly mudstone above		
	Rich, smooth, blue grey mudstone with *Carbonicola* ...	7	0
	Black barren paper shale (soft yellow grey weathering)	0	6
	Rough, hard, dark sandy mudstone with *Carbonicola* ...	2	6
	Micaceous shaly mudstone. Plentiful fish-scales ...	1	0
Bassy Mine	Coaly shale...	1	0
	Shaly coal and coaly shale with streaks of pure coal ...	1	0

The bed above the Lower Foot Mine,[1] which contains only estuarine forms in the east, has been found, farther west, to contain marine fossils.

In Birtle Dean the section at this horizon is as follows:—

	Ft.	in.
Dark platy shale above		
Dark grey shale with *Gastrioceras* and *Posidoniella* ...	0	6
Grey brown sandy shale with *Carbonicola*...	2	6
Grey shale with *Orbiculoidea* ?, *Naiadites* ? and *Carbonicola*	1	6
Coal (Lower Foot Mine)	1	0

This development of marine strata westward is of interest when

[1] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923.

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taken in conjunction with a similar development in the shales immediately above the Third Grit.

In the southern part of the area the beds between the Lower Foot and Lower Mountain Mines are shaly, but northwards a coarse sandstone occurs at this horizon. This rock is a hard, white siliceous sandstone, sometimes current bedded. It has a characteristic faint purple tinge in weathered specimens. On Whittle Pike and Higher Hill it forms a magnificent feature, which dominates the feature of the Woodhead Hill Rock below it. The rock is extremely variable in thickness; its base frequently cuts into the Lower Foot Coal, and often it dies out altogether.

Another very variable sandstone separates the Lower Mountain and Upper Foot Mines. The roof of the Lower Mountain is sandy mudstone, which passes upwards into dark sandy shale and soft dark shaly sandstones. These are succeeded by micaceous flagstone on which the Upper Foot Mine rests. In other localities, however, this rock is a hard siliceous sandstone in massive lenticular beds. The bases of these lenticles frequently cut across the bedding planes of the more normal sandy shale and shaly sandstone phase into the coal below.

This rock thins quickly towards the union of the two coals[1] and in the 'Union Mine' the strata which intervene elsewhere are represented by a streak of dirt or black bind. In Hapton Valley Colliery the union of these two coals has been examined[2] and the line along which the union takes place runs south-east. Between Hapton Valley Colliery and Deerplay scattered shaft sections, etc., show that this direction is maintained. West of Hapton Valley no information has been obtained.

The beds in the upper part of the Lower Coal Measures occur between Gambleside and Hapton Park. The structure is obscured by complicated belts of faulting, and exposures are scanty. The beds appear to maintain the character that they have in the Bacup district. In mapping this area much assistance has been obtained from mining information, for which we are indebted to Messrs. Geo. Hargreaves, Ltd., Rossendale.

In the area still farther east, surveyed by Mr. Lloyd, the Woodhead Hill Rock is normally overlain immediately by the Bassy Mine. An upper 'leaf' of the rock has been mapped in places, between the Bassy Mine and the Lower Foot Mine, and comparison of several sections shows this upper 'leaf' to be due to lateral replacement and not addition of strata. A lower 'leaf' also has been observed, occurring 15 or 20 ft. above the Six-Inch Mine. The shales above this lower leaf have been quarried for brickmaking at Shawforth.

The union of the Lower Mountain Mine with the Bullion Mine[3]

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[1] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 52.

[2] By courtesy of Mr. Clough, Manager of the Colliery.

[3] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), p. 52, and *Trans. Geol. Soc., Manchester*, vol. v., 1866, p. 186.

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to form the 'Union' Mine has been traced with the help of mining information,[1] beyond the limits formerly set down. North of this line of junction the Lower Mountain Mine, as 'Union' Mine, ranges in thickness from 4 to 6, and in rare cases even 7 ft., while south of it 'true' Mountain Mine (Lower Mountain Mine alone) varies from 2 ft. 6 in. to 4 ft., with an average of 3 ft. around Bacup. The coal is practically worked out immediately south of Bacup, but on the north side is still being won both as 'true' Mountain Mine and Union Mine. Sandstone lenticles (rigs) are fairly common in the Lower Mountain Mine, occurring entirely within the seam as trough-like wash-outs up to 20 yds. in width. Flat rigs also occur, giving a slightly thinner working seam with a rock roof. Near the junction of the two seams, the Bullion Mine Rock has been seen to form a 'swilly' in the Lower Mountain Mine, and its overlying shales, but this is local and exceptional.

The Bullion Mine marine band, immediately overlying the coal, is well exposed in the stream at Grime Bridge Colliery, and in several cloughs to the north-east. It is here not more than 6 in. thick, while at Scar End, where it overlies the Union Mine, the marine band is thicker and lies a few feet above the coal.

The Upper Mountain Mine remains fairly constant with an average of 1 ft. 6 in. North of Smallshaw Height, the crop has been found to lie above the line formerly mapped, so that a much less area of coal than has been assumed remains to be got here. Between Rushy Hill and Rooley Moor the Helpet Edge Rock[2] is well developed, coincident with which the Upper Mountain Mine shows a decrease in thickness and in places is represented merely by coaly streaks at the top of the fireclay; a clear example of this is seen in the River Spodden section at Healey, while the same feature is reported as a local phenomenon near Oldham by Mr. Lord, manager of Jubilee Pit.

The Pasture Mine horizon is represented at Sharneyford by a fireclay upwards of 10 ft. thick, which is mined by adits from the crop. The same fireclay crops out near the Irwell Springs Dye Works, brought up at a high angle by the Deerplay fault. The rock below this fireclay is the equivalent of the sandstones capping Tooter Hill, Brex Height and Stake Moss and contains a thin coal and fireclay which persists north as far as Burnley.

Middle Coal Measures.—The Middle Coal Measures are brought on west of Rochdale by a continuation of the southerly dip from the Rossendale anticline. The Royley Mine has been definitely correlated with the Arley Mine of Burnley by the characteristic succession of fireclays, thin coals, etc., underlying this 4-ft. seam. These are well exposed to the Naden and Ashworth valley and in

[1] We are much indebted to Mr. A. Lord, of Bacup, for ready help and information; and to Mr. Hunter, of Old Meadows Colliery, for facilities in examining the junction.

[2] 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922

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the Roche valley between Crimble and the Sewage Farm. The Riddle Scout Rock is thicker than in the Burnley area. An extended outcrop of the Arley Mine has been mapped on the north side of the Roche valley, and a more southerly extension of Middle Coal Measures has been proved near Rochdale.

W. B. WRIGHT.

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5. CUMBERLAND DISTRICT

Headquarters : Whitehaven

BERNARD SMITH, M.A.	District Geologist.
E. E. L. DIXON, A.R.C.Sc., B.Sc.	Senior Geologists.
T. EASTWOOD, A.R.C.Sc.	
F. M. TROTTER, M.Sc.	Geologists.
S. E. HOLLINGWORTH, B.A., B.Sc.	

In the Whitehaven district (Sheet 28) Mr. Eastwood has made progress in the coalfield about Workington, Harrington, and Distington ; whilst Mr. Dixon has advanced the survey of the Skiddaw Slates, Carboniferous Limestone and Coal Measures in the area between Greysouthern and Frizington. Mr. Hollingworth has mapped Skiddaw Slates and intrusive rocks in the neighbourhood of Ennerdale. New ground has been begun by Mr. Eastwood in the Lower Carboniferous rocks of the Bewcastle district (Sheet 12). He and Mr. Trotter together examined exposures of Upper Coal Measures south of the Liddel Water. Near Brampton (Sheet 18) Mr. Trotter has been engaged in investigating the sequence of the Carboniferous Limestone Series, and has mapped a spread of New Red rocks. Farther south, near Cumrew, Mr. Hollingworth has surveyed part of the Limestone Series and rocks from the Penrith to the St. Bees Sandstone. Interesting Glacial phenomena have been observed in all the districts.

Mr. Smith has consulted plans of hæmatite mines in Cumberland and Furness, and has examined many borings and deposits of ore in the field.

A special investigation in connection with the Carboniferous Limestone Series in the Cockermouth district, by Mr. C. Edmonds, has yielded results of value which will tend to accelerate the future detailed mapping of that area.

Skiddaw Slate.—In the neighbourhood of Ennerdale the Skiddaw Slate has been mapped eastward to its junction with the granophyre. Outside the area affected by this intrusion the slates occur in closely packed folds pitching in a direction varying between S.W. and S.S.W. On the west, however the granophyre is margined by a broad belt of unfolded slates with an average width of 1¼ miles and a general dip to the S.S.W.

South of Ennerdale Water this belt shows hardening due to the intrusion of the granophyre. This has resulted in a hornfels in which pink or grey bands represent thin beds of varying texture and composition. Farther south the aureole is much narrower, although the width of the belt of unfolded rock remains constant. From this it may be argued that the greater width of the altered belt is the result of intrusion of rock beneath or (originally) above this Skiddaw Slate, and is not due to that portion of the granophyre actually exposed farther east. The form of the boundary on Crag Fell suggests an underlying intrusion.

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On Bowness Knott, north of Ennerdale Water, a higher degree of metamorphism is apparent. Normal Skiddaw Slates have been mapped in the neighbourhood of Eaglesfield, several miles north of Ennerdale.

Buttermere and Ennerdale Granophyre.—About 3 sq. miles of the normal granophyre have been surveyed during the year. On the east of Bowness Knott a mass of basic rock,[1] veined and broken by granophyre, has been studied. Another patch of basic rock has been discovered as a mile-long strip in the crags on the south side of the lake at a general level of 1,000 ft. above O.D. At its western end, near the margin of the granophyre, it is 350 ft. in thickness. Thinning eastward it eventually dies out as a number of isolated knobs included in normal granophyre.

The occurrence of a distinct type of granophyre, with well-marked prisms of white felspar, overlying the basic rock of Crag Fell for some distance east of the point where the granophyre-hornfels boundary is approximately horizontal, suggests that the Skiddaw Slate originally extended eastward beyond its present limits at no great height above the present outcrop of the granophyre.

Dykes are rare. In addition to aplitic types[2] a beautiful acid dyke, with well developed and highly contorted spherulitic banding at its margin, has been discovered trending a few degrees north of east up the Scaw towards Starling Dodd. It is at least half a mile in length and apparently similar to that in Burtness Coombe[3] south of Buttermere.

Small dykes of rather basic types have been found on Bowness Knott, and short veins of felsitic material penetrate the Skiddaw Slates on the southern slopes of Bowness Knott and on Anglers Crag.

Fault lines occur in two directions in the granophyre, the one parallel to the length of the lake, the other trending N. 10° W. Hæmatite has been mined at several localities.

Carboniferous Limestone Series.—In the Whitehaven district (Sheet 28) work was continued in the neighbourhood of Eaglesfield, Greysouthern, Frizington and Arlecdon, where the outcrops are largely covered by Glacial deposits. Farther south (Sheets 28 & 37) the work was confined chiefly to a collection of records of bores and samples of cores, study of plans of working and abandoned hæmatite mines and examination of ore deposits *in situ*. This work was extended to Furness.

A tract of 12 sq. miles was mapped in the south-west corner of Sheet 12 (Shopford) in the neighbourhood of Penton and the River Lyne. Solid rocks are exposed intermittently in most of the stream-courses and belong in the main to the Carboniferous Lime-

[1] Rastall, R. H., 'The Buttermere and Ennerdale Granophyre,' *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 265.
[2] *Op. cit.*, p. 261.
[3] *Op. cit.*, p. 263.

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stone Series, although their true position in the sequence has not yet been determined. They comprise sandstones, mudstones and shales with thin limestones and coal seams, all more or less stained red. Evidence of considerable faulting, and some folding, frequently renders doubtful even the minor relationships of the strata.

Most of the sandstones are siliceous, whilst some of the thinner beds, occurring in clayey sediments, approximate to ganisters. Normal types are well displayed near Shanks Castle on the River Lyne, and the Rae Burn. In the upper reaches of the latter and in Hagling Burn the siliceous varieties are exposed.

Although forming but a small part of the sequence and seldom exceeding 3 or 4 ft. in thickness, many of the limestones yield fossils that will doubtless be aids to unravelling the structure and making correlation with other districts possible.

At Hagg Beck the most important of these beds is quarried on occasion for road-metal. It is said to be 9 ft. in thickness and yields a fairly extensive fauna. Some limestones are hæmatitised locally but are too lean to be worked as ores.

Several coals, with or without fireclays, occur in the district. Whilst some are very thin, others up to 2 ft. in thickness appear in the Rae Burn near Jenkinstown and Blackhouse, and also in Hagling Burn and on Mallsflow, where they were wrought up to about the end of last century. The Mallsflow coal seems to underlie the Hagg Beck limestone.

In the Brampton–Midgeholme district (Sheet 18) the rocks surveyed during the year fall within the Calcareous Division[1] (Upper, Middle and Lower Limestone Groups) of the Bernician, and consist of alternations of limestones with sandstones, shales and coal-seams.

Modifications have been made of several limestone boundaries laid down on the map of the previous survey and more continuous outcrops have been drawn. Outcrops of the thicker beds of sandstone, certain shale beds and thin beds of coal are new features upon the current maps. Two groups of faults complicate the structure, their general directions being E.-W. and N.W.-S.E. Of the first group the most noteworthy fault, a downthrow north of 40 fathoms, has been traced from Doles Hole (near Tindale Tarn) to Forest Head. Local synclines trend parallel to this group. On Tindale Fell beds from the Firestone Sill to the Four Fathom Limestone have been thrown up or down by faults of the second and numerically superior group, and now appear as craggy outcrops. In several quarries the thicker limestones are seen to be acutely folded on N.-S. axes which bear no relation to the general strike or dip or either of the two groups of faults.

Up to the present four limestones have been identified below the Tyne Bottom (Fig. 3). Near Low Row a trial shaft has proved

[1] Stanley Smith, 'Faunal Succession of the Upper Bernician,' *Trans. Nat. Hist. Soc. North.* and *Durham*, New Ser., vol. iii, pt. 3, 1910, p. 596.

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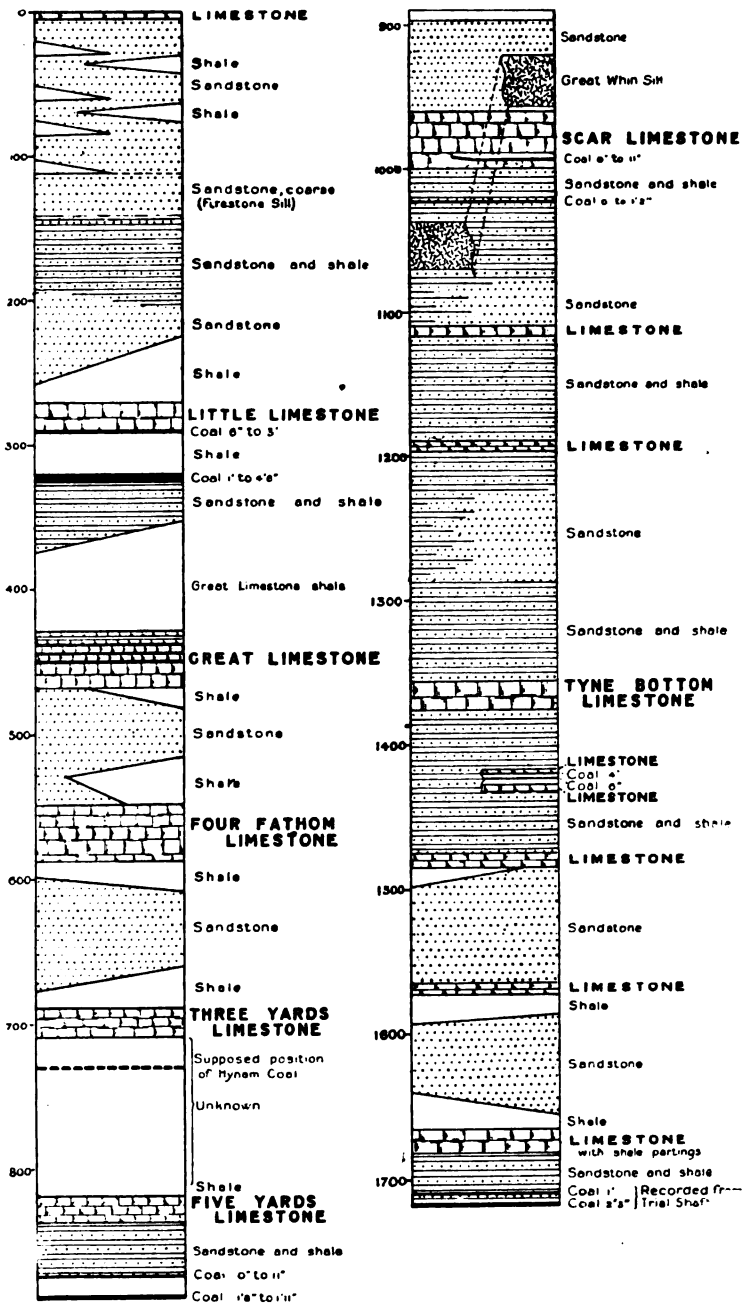

FIG. 3.—*Generalised Section of the sequence in the Carboniferous Limestone Series east of Brampton.*

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two thin coals beneath the lowest bed ; whilst in the same neighbourhood the limestone beneath the Tyne Bottom is divided by 5 ft. of black shale with two thin bright coals 4 and 6 in. thick. Farther south (in Sheet 24) the Jew Limestone, beneath the Tyne Bottom, is also underlain by a coal.

The sandstones that occur between the limestones beneath the Scar form imposing crags and have been quarried extensively.

The Tyne Bottom near Low Row is a compact limestone 20 ft. thick. The Single Post and Cockle Shell Limestones have been traced over but a limited area.

Near Low Row the Scar is a compact greyish white limestone with black cherts scattered sparsely throughout, overlying a calcareous sandstone. Towards the south-west a carbonaceous shale, resting upon a coal, which near Farlam Hill is from 6 to 11 in. in thickness, develops in its lower part. In Lyneholme Beck, between Farlam and Hallbank Gate, a coal hitherto unrecorded, 1 ft. 2 in. in thickness, occurs about 25 ft. below that mentioned above. Drifts were driven to both these Scar Coals in 1921-2, but are abandoned for the time being. Coal has been recorded at this horizon in the Cross Fell and Alston Moor districts.[1]

Two coals occur also about 70 ft. below the Five Yard Limestone and Westgarth Forster records coal at this horizon in the Cross Fell region. The lower seam, 1 ft. 9½ in., is about to be exploited for household purposes ; the upper is 11 in. in thickness.

Two further seams, measuring 8 in. and 4 in. respectively, lie still higher, a little below the Five Yards Limestone.

The Four Fathom Limestone (Second Limestone, Whitehaven) 40 ft. in thickness, occurs in massive posts and contains black cherts that tend to be concentrated in layers. It is surmounted by a hard felspathic sandstone frequently cemented by secondary quartz.

The Great Limestone (First Limestone, Whitehaven), which is underlain by a true ganister, is so constant lithologically that each bed has received a characteristic name. Totalling 40 ft. in all, the lower 18 consist of two (' main ') posts, whilst the higher beds are alternations of limestone and calcareous shale (' tumbler beds '). In places the main posts are acutely folded into sharp anticlines and synclines, the undulations becoming less and less pronounced in ascending through the overlying tumbler beds. A blue shale 50 to 80 ft. in thickness invariably overlies the limestone.

Numerous borings and surface exposures prove the existence of two persistent coals below the Little Limestone. The lower varies from 2 ft. 9 in. to 4 ft. 6 in. in thickness ; the upper, immediately below the limestone, varies from 4 in. to 2 ft. 6 in. The lower coal was worked on Tindale Fell about 100 years ago, and has been worked recently beneath Tarn Rigg and Denton Fell

[1] Westgarth Forster ' A Treatise on a Section of Strata from Newcastle-upon-Tyne to the Mountains of Cross Fell in Cumberland with remarks on Mineral Veins,' Ed. 2. 1821, p. 169 ; also Wm. Wallace, Section of Strata of Alston Moor (no date).

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from Howard and Roachburn Pits, now abandoned, although the coal is not exhausted.

The Firestone Sill varies from a coarse quartzitic rock to a soft micaceous and felspathic sandstone, or a fine grained non-micaceous sandstone.

The Whin Sill has been mapped for some distance near Carnetley. Another doleritic sill, 140 ft. thick, makes its appearance immediately below the Little Limestone in Black Burn, one mile N.N.W. of Midgeholme, Two newly discovered basic dykes have been traced for short distances.

Farther south, in the Cumrew area, the Carboniferous Limestone Series occurs to the east of the Pennine Fault. The lowest beds exposed form a strip half a mile wide, composed of a series of red grits and shales with pebbly conglomerates and grits that pass up with apparent conformity into more normal types. A small area of the latter, comprising beds from above the Great to below the Scar Limestone, has been mapped this year.

Millstone Grit.—Near Fishgarth, on the Eden, about 3 miles west of Cumrew, a small faulted inlier of purplish grey micaceous sandy shale and soft shaly sandstone, presumably of Upper Carboniferous age, appears surrounded by Penrith Sandstone.

Coal Measures.—At Workington about two square miles of Productive Coal Measures constitute a moribund coalfield, bounded on the north by the River Derwent and on the east by the Ellerbeck Fault. To the south it has been prospected as far as Moss Bay, and westward it extends for an average distance of a quarter of a mile beyond high water mark. The area is thickly covered by Glacial deposits; we are therefore dependent upon mining information[1] for the interpretation of its structure.

In general the measures dip seaward, but N.W. faults, with easterly downthrow, ensure the workable coals being seldom at great depth. The Great Coal—the Main Band of Whitehaven—about 10 ft. in thickness, was the chief seam worked; whilst coals are fairly evenly distributed in the overlying 600 ft. of strata in ascending order as follows:—Little Main, Moorbanks, Metal, Kennel and Brassey Bands.

These thin coals have been worked to a limited extent under Workington, north-east of a fault ranging south-eastward from near Isabella Pit by the Harbour. South-west of this fault lower seams were wrought, including the Great and the Yard and Hamilton—210 and 310 ft. respectively below the Great Coal. The identity of the Workington Yard Coal is obscure: it certainly is not the Yard Band of Whitehaven.

The Hamilton, or Hamilton Four Foot, appears to be the equivalent of the Six Quarters Coal.

North of the latitude of Moss Bay the outcrop of the Great Coal is repeated by faults several times. The most westerly crop

[1] Placed at our disposal by the Workington Estate.

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occurs close to the London, Midland and Scottish Railway, near the Steel Works, and runs out to sea in Moss Bay, where an attempt at robbery too close to the surface led to an irruption of the sea in 1837 and the drowning of the colliery.

Before this date the undersea workings had terminated westward at a N.N.E. fault, a supposed upcast west of 50 fathoms. This would have given dangerously insufficient cover for some distance beyond the fault, which, unfortunately, cannot be connected definitely with any other known dislocation. About a mile farther north, west of the Derwent Works, a bore at the western limits of the undersea workings indicated a nearly 20 fathom downthrow of the Great Coal seaward to a total depth of about 770 ft. below O.D., the level of the foot of Isabella Shaft. Here at least the cover is of sufficient thickness.

Between Salterbeck and Harrington the coalfield is unknown. Seams higher than the Six Quarters cannot be expected over much of the area; it is even probable that at Harrington itself the Harrington Four Foot, which is below the Six Quarters, has cropped out beneath the Glacial deposits.

A still larger unknown drift-covered area lies between the Ellerbeck Fault—an upcast east—and Stainburn, Winscales and Distington. The southern part, near Distington, would probably be barren of the more valuable seams, since they should crop out well to the north of the local uplift[1] of the Lower Carboniferous rocks. Between Winscales and Stainburn, north of the Wythemoor Fault, the chances of finding good seams appear to be more favourable.

A small tract of Coal Measures was examined near Branthwaite, farther east.

Upper Coal Measures.—Between Riddings Junction and Penton on the Liddel Water (Sheet 18) grey purple sandstones, thin local conglomerates and red, purple and pale mottled shales or marls make their appearance. They recall the Whitehaven Sandstone Series on the one hand and the Keele Beds of the Midlands on the other, and are well exposed in a dingle about half a mile south-west of Pentonbridge Inn, marked as Jockies Syke on a map[2] by Peach and Horne. The real Jockies Syke, however, from which plants were described by Dr. Kidston[3] demonstrating the Upper Coal Measures age of the beds lies half a mile to the south-west. The strata exposed in the two localities are essentially the same.

In Cumberland the relationship of these red beds to those beneath them is unknown; but across the Border they are believed to be conformable upon the Middle Coal Measures of Byre Burn[4]. Portions of cores found near the site of the Riddings

[1] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 65.
[2] 'The Canonbie Coalfield,' *Trans. Roy. Soc. Edin.*, vol. xl, 1903, Pl. I.
[3] 'The Fossil Plants of the Carboniferous Rocks of Canonbie,' *Trans. Roy. Soc. Edin.*, vol. xl, 1903, p. 811.
[4] 'The Canonbie Coalfield,' *Op. cit.*, p. 857.

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borehole[1] agree lithologically with the rocks exposed at Jockies Syke, and the descriptions in the record confirm the resemblance. There seems to be little doubt, therefore, that the Upper Coal Measures, due south of Riddings Junction, are transgressed unconformably by the St. Bees (Gypseous) Shales. The presence of the Carboniferous Limestone Series underlying the New Red beds in Carwinley Burn, one mile south-east of the Riddings borehole, postulates a pre-New Red fault of considerable magnitude between those two localities.

New Red Series.—In the Whitehaven area the brockrams of Permian to Triassic age have been further mapped or studied near Frizington and Arlecdon, and south of Egremont.

A limited spread of New Red rocks has been examined near Brampton. In Quarrybeck, which joins the Irthing at Lanercost, a thin breccia overlying Carboniferous Limestone forms an unconformable base to the series. It is succeeded by about 100 ft. of St. Bees Shales and St. Bees Sandstone. The absence of the great Pennine Fault is noteworthy. This site also is beyond the limits of deposition of the Penrith Sandstone.

In the Cumrew-Armathwaite district, about 8 miles farther south, Penrith Sandstone is exposed in the flank of the Eden valley, where it has been deeply dissected by gullies. In general it is a soft, poorly cemented, bright red, millet seed sandstone of variable texture with strongly marked false-bedding, At Fishgarth a hard pale sandstone, with secondary silicification, occurs about 200 ft. below the local top of the softer sandstone.

The junction between St. Bees Shale and Penrith Sandstone is not visible, and there are no signs of a passage between the two. In gullies draining west from King Harry's Common, the Shales pass up gradually, by the incoming of sandstone bands, into the St. Bees Sandstone which occupies most of the ground between the Eden and the Pennine Fault. It is a micaceous red sandstone with shaly bands practically confined to its lower beds. Between Cumwhitton and Hornsby large faults have been detected with a north-eastward trend.

Glacial.—In the Ennerdale valley deposits of the western (Irish Sea) ice, with erratics of Whitehaven and St. Bees Sandstone, occupy the ground up to the foot of the lake, but do not appear to have encroached on the hills to the south.

Local boulder-clay occupies a number of pre-glacial valleys in the higher ground to the north and south of Ennerdale, and morainic material covers much of the ground between Smithy Beck and the Scaw.

Late Glacial gravels, formed chiefly of Lake District materials, occur south of Cockhow and near Standing Stones; and were deposited at the latter locality in water held up by Irish Sea ice at 875 ft. above O.D.

[1] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 61.

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The overflows from glacial Lake Ennerdale can be recognised at 700+, 700−, and a little above 600 ft., draining down the Nannycatch Beck valley; the foremost east of Cockhow; the two latter south-west of that place.

The through valley between Flat Fell (north) and Dent (south) has been lowered at its eastern end quite 100 ft. to the floor of the Kirk Beck valley, which is the southern continuation of that of the Nannycatch Beck. This appears to have been effected first by the discharge of a local lake at between 600 and 700 ft., and later by the diversion of the outflow of Lake Ennerdale, then standing at about 550 ft., from the upper part of the Nannycatch valley round the west end of Flat Fell into the valley of the Kirk Beck.

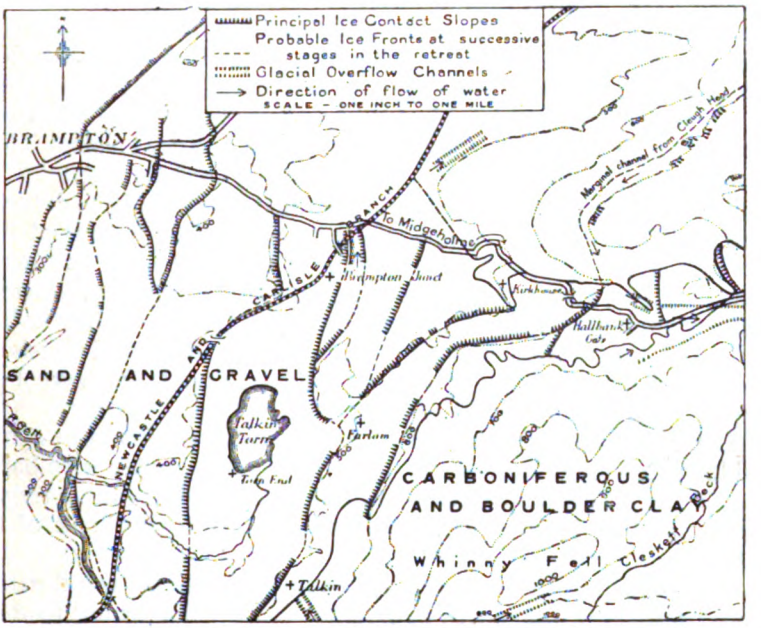

FIG. 4.—*Ice-retreat phenomena near Brampton.*

In the Bewcastle district the solid rocks are thickly covered by glacial deposits in which good sections are rare. The greater part is a red to grey boulder clay of variable consistency. Erratics from the Galloway area are mixed with those derived from local rocks. Near Easton a tract of sand and gravel represents a delta of a lake at about 400 ft. above O.D. Old drainage channels and other phenomena indicative of glacial lake conditions are common.

At the period of maximum glaciation in the Brampton district the Scottish ice swept eastward across the comparatively low ground north of the Cross Fell range into the valley of the South Tyne. The retreat phenomena of this ice-sheet in Tynedale have

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been ably described.[1] Its further retreat upon the western side of the watershed is equally interesting.

On shrinking away from the Pennines the ice dammed up a lake near Tindale Tarn at 900 ft., which drained into the head-waters of the Tyne *via* Midgeholme. A lake situated farther south discharged through a gap at 900 ft. near Whinny Fell into the Tindale Lake (Fig. 4). At a later stage a small lake was impounded near Cleugh Head, at 750 ft. dropping to 720-710 ft., and also drained into the Tyne near Midgeholme.

An important lake, referred to hereafter as the Farlam Lake, in which were deposited huge masses of sand and gravel, was held up at various levels in front of the retreating ice-front at successive stages. The highest known level is 700 ft., at which, and later at 660 ft., the water escaped by the Hallbank Gate-Midgeholme overflow into the Tyne. South-west of Hallbank Gate a long ridge of gravel, esker-like in shape, but parallel to the ice-front, was deposited between the latter and the fells. Lake deltas were formed at 700, 660, 550, 510–500, 480 and 450 ft. levels. Those at 450 ft. occur at more than one position of the ice-front.

Strand lines corresponding with certain deltas have been detected here and there. An overflow valley at 500 ft. discharged into the lake from the south, and a spur of ground to the north was breached by two successive outlets, at 510 and 450 ft., whereby the Farlam Lake drained into that of the Irthing valley, which in its turn overflowed into the Tyne by the abnormal Gilsland-Greenhead gap.[2] Some deltas of the Irthing Lake have been mapped this year.

Later the Irthing and Farlam Lakes became confluent at 450 ft. and lower levels, and thick masses of red laminated clay with bands of fine sand were deposited. Sections of these, to an aggregate thickness of at least 40 ft., are now exposed in the bank of the Irthing.

The ice-contact slopes of the Farlam Lake deltas trend nearly north and south, but north of Brampton Junction swing towards the north-east. Many are of considerable length and rise to a height of 100 to 140 ft., at an angle of about 40°. The position of the ice-front at different stages is obtained by joining up those ice-contact slopes that appear in alignment. Major and minor halts occurred during the retreat. Characteristic delta forms are best developed in front of the position of the more stable ice-fronts and form plateaux standing prominently from their surroundings.

The inclination of their lobate fore-set slopes varies, but is never so great as that of the ice-contact slopes. The deltas vary in width from point to point: when narrow, and when both ice-contact and fore-set slopes are steep, they appear as ridges

[1] Dwerryhouse, A. R., 'The Glaciation of Teesdale, Weardale and Tynedale,' *Quart. Journ. Geol. Soc.*, vol. lviii, 1902, pp. 572-608. A brief account of the glacial drainage of the western side of the Cross Fell Range has been published by Prof. P. F. Kendall, 'Geology of the Vale of Eden.' *Naturalist*, 1912, p. 110.

[2] Lebour, 'Geology of Northumberland and Durham,' 1886, p. 16.

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running parallel to the ice-front. A fine example of this type, 140 ft. high, trends N.30°E. from Brampton Town.

Deposition of sand and gravel in recognisable forms, in the ground between two consecutive positions of the ice-front, is proportional to the load of the englacial streams and varies inversely to the rate of retreat. During a comparatively quick retreat only the principal englacial streams deposit feeding eskers. Thus a large hollow, trending parallel to the ice-front, is left between the deltas formed at two consecutive major pauses in the retreat, and the hollow is divided into minor enclosed or partially enclosed hollows by the connecting eskers of the larger englacial streams. Talkin Tarn lies in such a basin.

With a less rapid rate of retreat the minor englacial streams deposit small mounds: the major streams, in a vain attempt to build deltas to the lake surface, leave an irregular hummocky drift. This is well exemplified in the ground south-west of Tarn End.

Farther south, in the Cumrew area, the evidence indicates that the last ice-movement in the Eden valley was a retreat of the Scottish ice. Hence the abundance of Lake District as well as Scotch erratics in the local boulder-clay necessitates the assumption of an earlier movement of Lake District ice down the Vale.

During the final retreat glacial lakes were formed and marginal drainage channels cut in numbers on the eastern flanks of the Vale. Local lakes were impounded in the valley of the Croglin Water (Sheet 24) at 700 and 585 ft.; while at the lower levels of 540, 450, 400 (?) and 375 ft. more widespread lakes occupied much of the ice-free upper parts of the Vale of Eden. Down to a level of 450 ft. the drainage was towards the South Tyne, *via* the Brampton district, as described above. Below that level the water probably travelled westward, north of the Caldbeck Fells.

Near Carlatton the stages in the retreat can be recognised in a series of sand and gravel ice-contact slopes trending north and south, which will be found to link up with those of the Brampton area.

BERNARD SMITH.

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6. NORTHUMBERLAND AND DURHAM DISTRICT

Headquarters: Newcastle-on-Tyne

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During the past season the field work of the Northumberland and Durham unit dealt mainly with Lower Carboniferous areas between the Cheviots and the sea coast south of Alnmouth. Mr. Carruthers revised the country north and east of Alnwick, Mr. Burnett the Breamish valley north and east of Brandon, and Mr. Anderson the adjoining ground as far as Whittingham: all this work lay in one-inch Sheet 6. Farther south, in Sheet 9, Mr. Fowler was engaged in the Rothbury district, moving later on to the Coal Measures tract south of Warkworth; and Mr. Maden, continuing his work in the Longhorsley district, revised the moorlands around the headwaters of the Font.

It is not surprising to find that some alterations and many additions have been made to the published maps, for these were originally executed by Mr. Topley forty years ago. In general the sequence and character of the strata concerned agree well with those found, within the last few years, to hold good over more northern areas. The most notable variation is in the Scremerston Coal Group, which is so attenuated south of the Aln valley as to be of little economic value; some compensation for this is found in the fact that, amongst the Limestone measures of the same region, the Shilbottle house-coal attains its maximum development. There are abnormalities also in the development of the Cementstone Group: the local base, west of the Breamish valley, is a massive conglomerate several hundred feet thick, and in the Rothbury country some of the cementstone bands are as much as 19 ft. thick, a striking contrast to the mere ribs prevailing further north. From the structural point of view the chief item of general interest is the occurrence of extensive lateral movement along east-and-west faults between Alnwick and the coast.

Previous work on glaciation around the Cheviot foot-hills[1] has been confirmed and some additions made to the remarkable series of late glacial phenomena so prominent in this region.

Cementstone Series.—Around Ilderton, on the west side of the Breamish valley, Mr. Burnett has examined the coarse conglomerate of Roddam Dene. It has long been known that these rocks rest unconformably on the Cheviot lavas, but their classification has

[1] *See* J. A. Smythe, 'The Glacial Geology of Northumberland,' *Trans. Nat. Hist. Soc. Northumberland*, New Ser. vol. iv, 1912. A more general account is given by P. F. Kendall and H. B. Muff, *Geol. Mag.*, 1901, p. 513, and *Trans. Edin. Geol. Soc.*, vol. viii, 1902, p. 226.

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been in doubt. They are certainly abnormal, for as a general rule strata of ordinary Cementstone type transgress directly on to the Cheviot lavas, with but a few feet of purple breccia and marl in their lowest layers. Mr. Topley himself mapped the Roddam Dene group as basal Carboniferous, but in the Index accompanying one-inch Sheet 6 correlated them with the Upper Old Red Sandstone of Scotland. Unfortunately palaeontological evidence seems to be entirely lacking, and although one or two good field-sections can be seen, notably in Roddam Dene itself, a junction with undoubted Cementstone strata has not yet been found. On general grounds, there seems little reason to doubt that we are dealing with a purely local conglomerate marking the base of the Carboniferous rocks, a pocket accumulated in a deep hollow of the eroded lava surface. No true estimate of the thickness of the group is possible : it may perhaps be 400 ft. It is worthy of note that, by estimation, the overlying Cementstone Series is not more than 1000 ft. thick, for the Roddam Dene conglomerates lie hardly more than two miles west of the Fell Sandstone escarpments on the right bank of the river Breamish ; if no fault intervenes it seems likely that much of the 3,000 or 4,000 ft. of Cementstones in the Tweed valley had already accumulated before the Roddam Dene breccias were laid down.

South of the Breamish, all trace of the conglomerate vanishes : Mr. Anderson has noted greenish shales of the usual Cementstone type only 40 to 60 yds. away from lava outcrops in the streams north of The Mile farm, and at Great Ryle. He reports that in the Whittingham district the whole series is probably 2,000 ft. thick. A typical succession of greenish-grey shale with ribs of cementstone and sandstone posts can be seen in the railway cutting one mile north of Glanton Station, at the tunnel mouth north of Edlingham, and in the cutting at the foot of Corby Crags : similar beds occur alongside the river on the western fringe of the Hulne Park, Alnwick.

South of the Cheviots there is considerable expansion of the Series, this being especially noticeable in the bands of earthy cement or limestone. West of Rothbury Mr. Fowler has noticed a thin-bedded cement limestone fully 10 ft. thick at Warton, and that outcrops of other bands in this neighbourhood are marked by extensive deposits of calcareous tufa. South of the Coquet a limestone 15 ft. thick is seen at Whitton Dene, and in the Glebe quarry 18 ft. of well-bedded cementstone is now being quarried for road-metal. Swallow-holes are not uncommon in these thick limestones, and there are powerful springs along the outcrops near Tosson, no doubt fed from the massive sandstones of the Simonside Fells.

Fell Sandstone.—Between Alnwick and the Breamish valley, escarpments of the Fell Sandstone are frequent, there being much repetition through step-faulting. These strata, in all about 800 ft.

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thick, call for no special remark : as usual, massive, false-bedded buff sandstones prevail, often with coarse pebbly bands : the stone is generally too friable and irregular to be of economic value. Mr. Anderson finds that the lower beds often contain spherical pockets up to 3 ft. in diameter, filled with a soft yellow sand : this feature is well seen in the railway-cutting north-east of Edlingham Station, and at the same spot an undisturbed, conformable junction with the underlying Cementstone Group is clearly exposed.

Around Rothbury, Fell Sandstone accounts for most of the high ground, the great escarpments of the Simonside Fells being particularly noteworthy. Mr. Fowler states that coarse bands, with quartz pebbles up to one inch in diameter, are fairly common.

Scremerston Coal Group.—This series, although perfectly recognisable southwards to Rothbury, is of little economic account in the areas revised. A few coal workings are known, but they are all on a small scale, and have been so long abandoned that hardly any record of them exists. Only at one locality, east of Eglingham, have we any definite account of the seams wrought. Mr. Burnett reports that two coals were mined here, the top one 2 ft. thick, with a 3-in. stone band in the centre, and 45 ft. below it, the Bottom Coal, 32 in. thick, including a 6-in. rib of shale.[1] The lower seam appears to be that wrought in the Shipley Colliery, 1½ m. east of Eglingham, so recently as 1905, but it was there only 22 in. thick, including a 5-in. ' band.'

We have not sufficient data as yet for a correlation of these coals with the well-known seams farther north : one point that may be of value is the presence of a dark crinoidal limestone, noticed by Mr. Burnett in the Coal Burn 200 ft. N. of the West Ditchburn farm road. This limestone may be that recorded by G. Tate 2½ ft. above the Main Coal in the Bannermoor Pit section, and if so is probably the equivalent of the Duddo Limestone, lying beneath the Fawcet Coal in the Berwick-Etal district,[2] and the only true marine limestone so far recorded within the Scremerston Group.

South of Shipley the coals are cut off by a large east-and-west fault, but reappear west of Alnwick, where there are many shallow pits of ancient date on the outskirts of the town. Good sections of the coals and their associated strata are not common in this district : the best, perhaps, is that seen in the Stocking Burn just within the eastern border of the Hulne Park. Nearly 100 ft. of strata is exposed here, including two well-defined marine horizons, the Dun Limestone and the Duddo Limestone. Both are of dark crinoidal type, as in northern areas : under the Duddo Limestone is an 18-in. coal, while there are old workings in a lower seam a few yards farther downstream. The identification of the limestones is new, and has an important bearing on our knowledge of the local

[1] *See* G. Tate's account of the Bannamoor Pit section, *Proc. Berw. Nat. Field Club*, vol. v, 1867, p. 283, etc.

[2] ' Summary of Progress ' for 1921 (*Mem. Geol. Surv.*), 1922, p. 70.

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structure : it reveals the presence of an east-and-west fault, down N. 80 fms. or more, the Dun Limestone being repeated south of Alnwick, with the same S.S.E. dip as in the Stocking Burn.

A mile north of Rothbury, Mr. Fowler reports that thin coals have been wrought on each side of the main road to Alnwick, and sections of the associated strata are visible to the west, in the Debdon Burn ; at Debdon he has found shales with marine lamellibranchs of the *Sanguinolites* type, and imperfectly preserved remains of *Euphemus* or *Bellerophon*.

The Limestone Group.—Although there must be a full sequence of these strata in the Alnwick district, little is actually seen of the lower members. The Dun Limestone, at the base of the group, outcrops in the Hulne Park, as already noticed, and it has again been found near Hefferlaw Tower, with the Oxford Limestone appearing in two isolated exposures further east, towards Broxfield ; these identifications have been of much use in deciphering a tract of obscure ground 3 miles north of the town.

Between the Oxford and Eelwell limestones, the only horizon calling for notice is a buff-coloured freestone of particularly fine quality. This stone, which is largely used for ornamental work, is quarried east of Denwick. In the older quarries it is from 16 to 20 ft. thick, but the overburden is now so heavy that a new working has been started on the north side of the Denwick-Long Houghton road ; there is no cover here, but the stone is naturally rather jointy and affected by surface alteration.

The chief beds of limestone are found towards the top of the Group. The sequence agrees perfectly with neighbouring areas, but the nomenclature is different, as will be seen from the comparative table set out below.

Middle Limestones in Northumberland

Berwick, Beadnell, &c.	*Alnwick District.*
Great or Dryburn Limestone	Great or Ten-Yard Limestone
Sandbanks Limestone	Eight-Yard Limestone
Acre Limestone	Six-Yard Limestone
Acre Coal	Shilbottle or Metal Coal
Eelwell or Beadnell Limestone	Nine-Yard Limestone

Between Long Houghton and Alnwick these limestones are clearly seen, all of them having been quarried at one time ; each has special characters by which it can, as a rule, be recognised without difficulty. The Great Limestone is a sugary-looking crinoidal stone, often extensively dolomitised : in this district it is relatively unfossiliferous : a few coarsely ribbed *Productus giganteus*, and *Lonsdaleia* are scattered through the upper parts, while in the bottom layer Orthotetid casts are often abundant. The barren, fine-grained and earthy-looking upper beds of the Eight-Yard Limestone are unmistakable, while the Acre or Six-Yard

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Limestone, dark and crinoidal, shows an abundance of *Saccamina* in the uppermost layers, and in particular small corals (*Zaphrentis eruca* and *Cyathaxonia cornu*) peculiar to this horizon. Little is seen of the Eelwell Limestone, but it certainly retains the rib of Orthotetid shells, so characteristic of its upper surface farther north.

Attention has been drawn to diagnostic features in the various limestones, owing to their value in reading the local geological structure : they have proved especially useful in the Long Houghton-Denwick area. An important east-and-west fault runs through Long Houghton, and a map showing its course west of that village is appended (Fig. 5). The fault is first seen on the coast north of Boulmer, where it brings Millstone Grit against the Foxton Hall Limestone (the highest in the Upper Limestone Group). Supposing the fault to be a normal one, this would amount to a downthrow north of about 300 ft. Farther west, no disturbance is apparent for nearly three miles, and in the Ratcheugh limestone quarry (Fig. 5) the outcrop of the Great Limestone crosses the fault line with little or no apparent break. On the north side of the fault, going westwards, the Great Limestone, gently undulating, remains more or less parallel to the fault for a long distance, but on the south side a steady south-east dip sets in, eventually bringing up the Eelwell Limestone and still lower strata against the Great Limestone. In less than a mile a fault of little or no account at Ratcheugh has apparently increased to a downthrow north of 400 ft. or more. The marked south-east dip, seen on the south side of the fault west of Ratcheugh, reappears on the north side 1½ or 2 miles farther west.

If the Long Houghton Fault be regarded as a normal one throughout its course, then sudden ' sags ' of 300 or 400 ft. have to be invoked at more than one point, accompanied, furthermore, by abrupt changes in the strike and inclination of the strata. Alternatively, the dislocation may be regarded as due wholly to lateral shift, the displacement amounting to 1½ miles or thereabouts : some confirmation of this reading is supplied by the presence of horizontal slickensides on the fault plane at the coast, and in a small branch seen in the limestone quarry at Ratcheugh.

Lateral movements of great magnitude probably occur elsewhere in the district : there is at least one example south of Embleton. Such movements seem to be restricted to the east-and-west faults : wherever these coincide with abrupt changes of strike and inclination, lateral movement of the local structure can generally be found. The phenomenon may be more common than is generally supposed : it will be recalled that in the San Francisco earthquake of 1906, the San Andreas rift had a horizontal displacement of 21 ft., the vertical shift being only about a foot.

The map (Fig. 5) brings out a further point of some interest. There is often reason to suppose that intrusions of the Whin Sill in Northumberland took place after the major faulting, but actual

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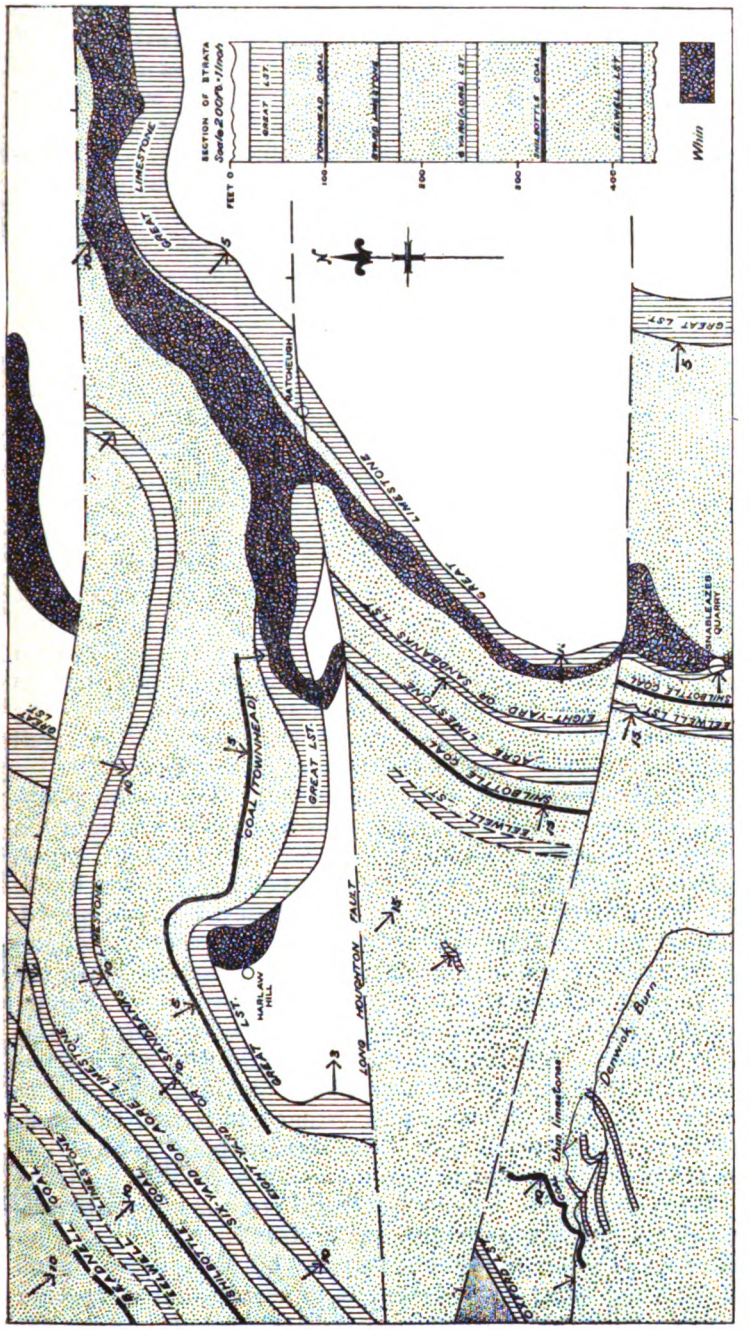

FIG. 5.—*Map of the Lower Limestones between Denwick and Little Houghton, north-east of Alnwick.*
Scale, 3 inches to 1 mile.

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proofs are rarely to be found. South-west of Long Houghton the quartz-dolerite sill, shown on the map, has been intruded immediately beneath the Great Limestone, and can be followed south of Ratcheugh in a continuous series of crags ending at Snableazes quarry. For nearly a mile the Great Limestone is seen resting uninterruptedly on top of the dolerite, maintaining its normal characters, apart from contact alteration, all the way. At Snableazes, however, there is an abrupt change; a thick limestone is seen immediately beneath the sill, but it is the Acre or Six-Yard Limestone, and, marmorization apart, agrees exactly with the excellent sections of the Six-Yard seen in old quarries half a mile to the south-east. The dolerite sheet, without change of alignment, has crossed a fault fully 200 ft. down north.

In his investigation of the Lower and Middle Limestone measures around Rothbury, Mr. Fowler reports an exposure of the Dun Limestone about two miles north-west of the town, and east of the road to Alnwick. *Lithostrotion* is common, along with the finely-ribbed variety of *Productus giganteus* peculiar to the Dun-Woodend horizon in Northumberland and the Scottish Border. The limestone south-west of Hope shows *Girvanella*-like nodules, and may represent the Oxford Limestone. There are good sections in the Forest Burn near East Row: the lowest limestone seen is at least 10 ft. thick and in all probability is the Eelwell, an horizon not exposed elsewhere for many miles. The Shilbottle Coal is seen in the bed of the stream near Bushygap Cottage, and representatives of the 'Red Bed' and the 'Little Limestone' outcrop along the banks close by: these strata are impure sandy limestones, well known as local 'marks' for the underlying Shilbottle Coal.

In Mr. Maden's revision of the moorlands west of the Rothbury-Morpeth railway, the chief point of interest is the recognition of the Oxford Limestone along an outcrop of nearly six miles. This important datum line is first seen in the Forest Burn, half a mile west of the Hut, where fully 19 ft. of limestone are exposed. The characteristic *Girvanella*-like concretions, seen both as nodules and around fossils, are present in abundance. Farther south the limestone reappears half a mile west by north from Newbiggin, and in many broken exposures along the Fallowlees Burn, up to the Old Lead Mine. A noteworthy feature, confined to the Fallowlees sections, is the occurrence of a true ganister rock, from 2½ft. to 3 ft. thick, 12 ft. or so below the limestone: it is buff-coloured, full of rootlets and even in grain. The melting point is high, but the stone is scarcely hard enough to rank as a first-quality ganister.

Mr. Maden visited the Farne islands and confirms many details in the excellent accounts furnished by W. Gunn.[1]

Specimens of the limestones noted by Mr. Gunn were collected, but the contact alteration is so severe that it has not been possible to identify them with any known seams on the

[1] Gunn, W., 'The Geology of Belford, Holy Island and the Farne Islands' (*Mem. Geol. Surv.*), 1900.

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mainland. Mr. Maden considers them to be inclusions, a point not quite clear in the published accounts.

Coal Measures.—The revision of the Coal Measures south of Amble and Warkworth was started late in the season, but enough has been done to show that considerable alteration of the old maps is required: much new information has been afforded both from bores and colliery plans.

In the Newcastle district, Mr. Maden, continuing his previous work, has revised areas around East Denton and north of Scotswood. Two coals outcrop towards the mouth of Denton Burn: the bottom one is probably the Low Main, one of the leading seams in the district, but the upper coal was wrought under that name until quite recently. This correlation seems to be incorrect: the coal worked has several partings of shale up to a foot thick, a feature never recorded in the old records of the Low Main in the immediate neighbourhood.

Mr. Anderson, working south of the Tyne, has completed his examination of the lower reaches of the Derwent. The sequence agrees with that recorded in the 'Summary of Progress' for 1922, and new outcrops of five coals, from the Brockwell up to the Low Main, have been traced along the valley sides. A large contemporaneous 'wash-out' has been found in the Brockwell Coal, starting at Saltwell Park, Gateshead, and running due west for 3½ miles: at Whickham it is 1200 yds. wide. The overlying coals are not affected.

Glaciation.—The final break-up of the ice-sheet round the Cheviots gave rise to many features of interest in Mr. Burnett's area round the Breamish valley. In the broad hollow between the Cheviot foothills and the ring of Fell Sandstones to the east, which may conveniently be termed the 'Hedgeley Basin,' a great mass of dead ice accumulated. As this melted, extensive tracts of 'kettled gravel,' covered with mounds, and seamed with water courses, were deposited west of the river, up to the 500-ft. contour line. At an earlier stage marginal channels and 'truncated spurs' were cut, of which the most notable example is in Brandon Dene, with its intake near Roddamrigg House. After the ice in the Hedgeley Basin began to melt away a new cut was made towards Wooperton: later still the whole drainage must have passed southwards through the great Crawley Dene-Shawdon gorge, now followed by the railway: this typical glacial overflow, fully 3½ miles long, is one of the most imposing of its kind in Northumberland.

East of the Breamish Mr. Anderson records a clear marginal cut, 1½ miles long, under the sandstone escarpments south-east of Beanly: evidently this was made at a relatively early period, when the ice completely filled the Hedgeley Basin.

Marginal channels and overflows associated with the retreat of the ice up the valley of the Aln have been observed at Freeman's

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Gap, 2 miles west of Alnwick, and in the deep cut which joins the Shipley Burn below South Charlton. Longlee Moor, immediately to the west, is covered with ' kettled ' sands and gravels, amongst which a well-marked ridge running towards South Charlton is considered by Mr. Burnett to be an esker.

The two boulder clays, products of a single ice-sheet, which have been noticed over wide areas in North Northumberland,[1] have now been observed by Mr. Maden in the Newcastle district. On the north bank of the Tyne, 300 yds. below the mouth of the Ouseburn, a long cutting has recently been made. Over a stretch of about 150 yds. two boulder clays are seen, with an irregular parting of sand and gravel betweeen. The lower clay is stiff and dark, with many large boulders of limestone : hardly any were to be seen in the upper clay or in the sand and gravel between. The sand is on the whole clean and well-bedded, but in places there is some contortion of the upper layers, clearly visible when seams of a fine gutta percha clay happen to occur.

South of the Tyne Mr. Anderson reports that along the line of the Team valley wash-out, above the 300-ft. contour, the boulder clay contains many stones of far-travelled origin : Borrowdale Volcanics are very numerous, along with examples of Skiddaw, Threlkeld and Dalbeattie granites. Curiously enough, Cheviot igneous rocks, elsewhere common enough, do not seem to occur in this assemblage.

Overflow channels, belonging to the final stages of glaciation, have been noted at Byermoor Colliery, from Marly Hill Colliery to Marshall Land, and near Long Hill.

R. G. CARRUTHERS.

[1] ' Summary of Progress ' for 1922 (*Mem. Geol. Surv.*), 1923, pp. 76–77.

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(B)—SCOTLAND

1. AYRSHIRE

E. B. Bailey, M.C., B.A., District Geologist.
J. E. Richey, M.C., B.A., Senior Geologist.
V. A. Eyles, B.Sc.
J. B. Simpson, B.Sc.
A. G. MacGregor, M.C., B.Sc. } Geologists.

Work has been carried out in two distinct areas, which are described below under the headings North Ayrshire and Central Ayrshire.

North Ayrshire

Mr. MacGregor has investigated the Lower Old Red Sandstone south-east of Darvel, with its important acid plutonic complex, and has co-operated with Mr. Richey in his work upon the Calciferous Sandstone lavas north of the River Irvine. Reference has already been made in former Summaries[1] to occurrences of trachyte among the volcanic necks and lava flows of this district. The generalisation may now be made that, in the later part of the Calciferous Sandstone volcanic period, a number of vents emitting relatively acid materials were grouped about a line extending west-north-westwards across one-inch Sheet 22, from Loudoun Hill (one-inch Sheet 23) to Misty Law (one-inch Sheet 30). Towards the west, trachyte lava-flows have rarely been noted, but trachyte occurs in the vent of the Knockside Hills[2], and comprises the twin plugs of Lochlands Hill north-east of Beith. East of Lugton and Uplawmoor a few plugs are also found (Blacklaw, Neilston Pad, etc.), and there are extensive outcrops of trachyte lavas.

Certain conclusions regarding the geographical conditions prevailing near the close of Calciferous Sandstone times are summarised below by Mr. Richey.

1. The Calciferous Sandstone lavas, which are of great thickness to the north, were, to a large extent at least, poured out subaerially. They reached southward to the shore of a lagoon-area in which cementstones, either previously or simultaneously, were deposited.

2. After the close of the main volcanic period, the lava pile was depressed, and a gulf came into existence which extended north-eastwards across Sheet 22, and communicated with the Renfrewshire area of deposition (Fig. 6). In it the Upper Calciferous Sandstone sediments were laid down. A land area, at any

[1] Richey, J. E., 'Summary of Progress' for 1919 (*Mem. Geol. Surv.*), 1920, p. 27; Richey, J. E., and G. A. Burnett, 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 48.

[2] Wilson, G. V., 'Preliminary Notes on Volcanic Necks in North-west Ayrshire,' *Trans. Geol. Soc. Glasgow*, vol. xvi, 1916, pp. 1 and 92.

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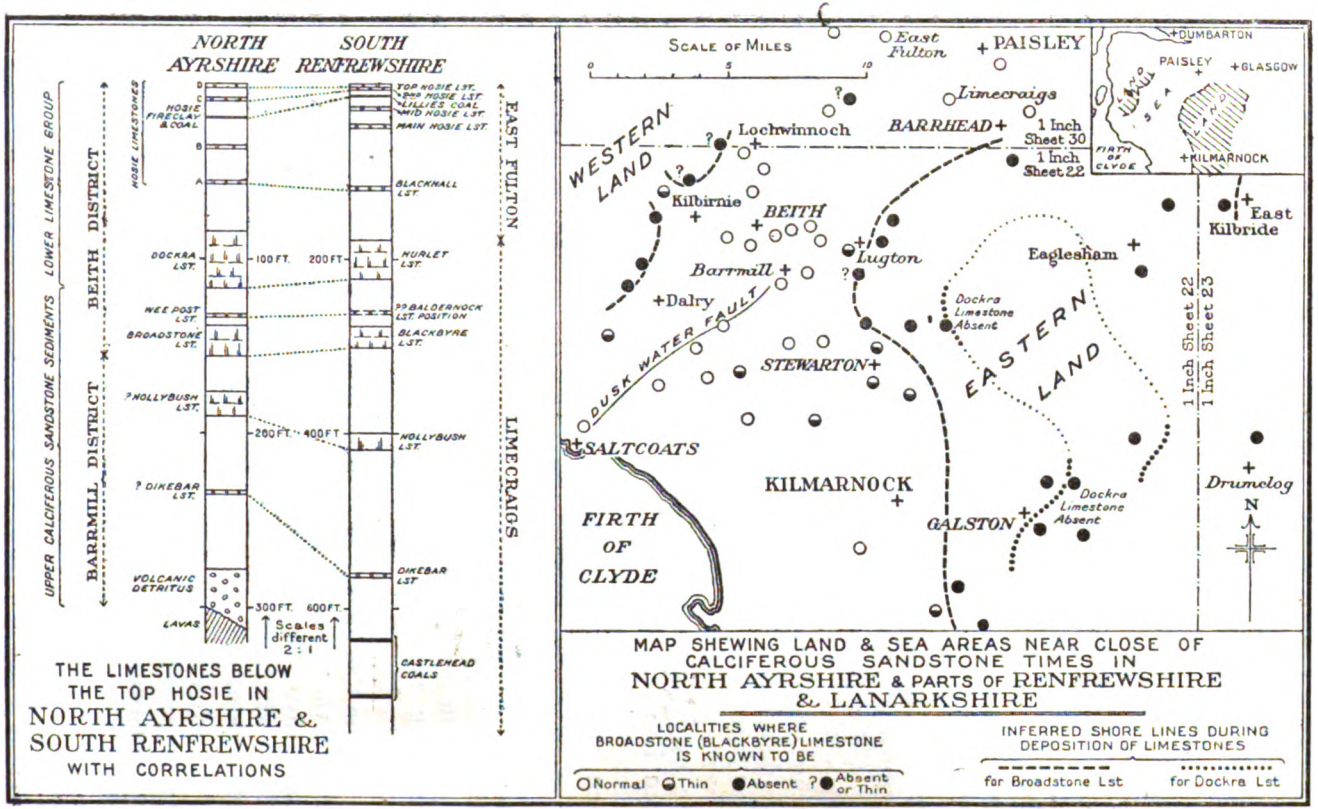

FIG. 6.

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rate a dozen miles in width, bordered the gulf to the east. To the west land also existed, but its extent is unknown.

3. Subsidence continued, and thus the Dockra (Hurlet)[1] Limestone (the lowest seam in the Lower Limestone Group) was deposited over a wider area than underlying beds. A portion, however, of the eastern land persisted. Last year, instances of the local absence of Dockra Limestone were cited,[2] and, at the conclusion of this summary, Mr. MacGregor describes sections where the lowest normal sediments above the volcanic pile are referable to the Limestone Coal Group.

4. One or both of the Lower Hosie Limestones, which are present in the north part of Sheet 22, are absent to the south-east, where the Dockra is the first limestone below the two top Hosies.[3] This may be due to a slight unconformity of which there is independent evidence at the top of the Dockra throughout much of North Ayrshire.

5. The disappearance of two Hosie Limestones, just referred to, suggests differential movement on a small scale. There is also evidence that the more important overlap, which characterises the base of the post-lava sediments, was controlled by differential movement rather than by original unevenness of the volcanic platform :—

(*a*) In the north of the area where the lavas appear to be at their maximum thickness, the top group of the local lava sequence (basalts of Dalmeny Type) is exposed on both sides of the sediment-filled gulf between, and its continuity is established by intervening exposures. It seems probable, therefore, that the depression did not exist when these lavas were poured out.

(*b*) As the lava group is followed south along the west side of the gulf, it is clearly seen to diminish greatly in thickness, but this diminution is unaccompanied by any evidence of corresponding early submersion.

(*c*) Towards the southern end of the eastern land of Fig. 6, the overlap is particularly marked in spite of the fact that the volcanic rocks are unrepresented in certain sections. Near Cairnhill, 3½ miles south-west of Galston, the Dockra Limestone rests almost immediately upon the Cementstone Group, and near Cessnock Castle, 1 mile south-east of Galston, the Upper Hosie Limestones overlie Upper Old Red Sandstone.

6. During Carboniferous times in Scotland, recurring cycles of sedimentation often begin with a limestone and end with a seam of coal. These cycles are considered to indicate periods of rapid depression alternating with longer intervals during which

[1] Carruthers, R. G., and J. E. Richey, 'The Lower Limestones of Renfrewshire and North Ayrshire,' *Trans. Geol. Soc. Glasgow*, vol. xv, 1915, p. 249. The Dockra has alternatively been correlated with the Blackbyre. P. Macnair, 'The Hurlet Sequence in North Ayrshire,' *Trans. Geol. Soc. Glasgow*, vol. xv, 1915, pp. 200-248.

[2] Richey, J. E., 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, pp. 80, 81. The only other district of southern Scotland, where the Hurlet Limestone is known to be absent owing to overlap on to older rocks, is the Sanquhar coalfield.

[3] Richey, J. E., *op. cit.*

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sedimentation went on, till finally silting up and growth of vegetation with the formation of a coal seam occurred.[1] Consequently the amount of sedimentation at any locality during one or more complete cycles may be taken as a measure of the amount of crustal depression involved. Along the line of the North Ayrshire gulf, the Upper Calciferous Sandstone sediments, from the lowest (Dikebar) limestone to a fireclay and coal at the top of the series, decrease in thickness south-eastwards from the Paisley district (Fig. 6). This suggests crustal depression deepening towards Renfrewshire.

7. This view agrees with the later history of the region. The succeeding sediments, from the base of the Dockra (Hurlet) Limestone to the base of the Index Limestone, also decrease gradually in thickness south-westwards from Paisley through Kilbirnie and Dalry towards Saltcoats.

8. The general south-westward attenuation of the Limestone-Coal Group noted under (7) is less marked than another change to which Mr. Anderson draws attention. In the district near Dalry the Limestone Coal and Upper Limestone Groups are thick and their succession is fairly constant. Passing eastwards beyond a line coinciding roughly with the Dusk Water Fault, both groups are thin, and although there are minor variations they do not, for a long distance, attain anything like their Dalry development (Fig. 6.) It appears, therefore, that pronounced differential movement occurred approximately along the Dusk Water Fault during Limestone Coal and Upper Limestone times.

Under paragraph (3) of the preceding summary, reference is made to sections where sediments of the Limestone Coal Group rest directly on the detrital covering of the Calciferous Sandstone lavas. Nothing quite comparable with this has previously been recognised in Scotland; and accordingly Mr. A. G. MacGregor furnishes a few details concerning the most typical exposures.

In the Glen Water, where it is joined by the Mucks Water from the west (about 1¾ miles north of Darvel), and in the Mucks Water itself, it has been found that there is an upward passage from olivine-basalt (approaching the Dalmeny Type) through volcanic detritus, perhaps including ash, to blaes, sandstone and thin coals. A generalized section is as follows :—

	Ft.	in.
Rusty quartzose faky sandstone	8	0
Dark blaes with clayband ironstone nodules	11	1
Coal	0	7
Fine-grained rusty carbonaceous sandstone with many *Stigmariae*	3	6
Dark fireclay	0	6
Coal	0	9
Dark fireclay	1	6

[1] Peach, B. N. 'Some Points in the Natural History of the Carboniferous Period in East Scotland,' *Proc. Royal Phy. Soc. Edin.*, vol. xix, 1916, pp. 251-252.

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	Ft.	in.
Black blaes with clayband nodules	10	0
Dark irony fine-grained ashy detritus...	0	9
Dirty white marly blaes	1	0
Fine grained marly " ashy " mudstone, and some bands of pale creamy fireclay-like material which suggest lateritic weathering	14	6
Volcanic detritus (carbonaceous at top)	22	0
" Ashy " beds (? detrital)	15	6
Basalt lava ... ... at least	25	0

Here, then, no limestones are found at all, and the non-volcanic sediments begin with a considerable thickness of blaes. The assemblage of blaes, sandstones and thin coals is unlike anything found in the Calciferous Sandstone Series or Lower Limestone Group in this neighbourhood. The lithology of the sediments suggests that they are of Limestone Coal age. The upper part of the volcanic detritus on which they rest may possibly represent a coastal development of the Lower Limestone Group, but of this there is no certainty.

The extreme overlap thus indicated is quite local. Two and three-quarter miles south-westward, in the Huggin Craig Burn, Limestone D of the Hosie Group has been recognised by Mr. Richey resting almost directly on ashy-like detrital beds; and three-quarters of a mile farther west, in the Hag Burn, an oolitic facies of the Dockra Limestone is found, full of volcanic debris. Eastwards, the reappearance of the Lower Limestone Group is even more sudden, for the Dockra Limestone is met with only two miles east of the Glen Water, not far west of Drumclog.

Central Ayrshire

In the following account Mr. Eyles is responsible for the western half of the district, and Mr. Simpson for the eastern. Partial accounts have already appeared in 'Summaries of Progress' beginning with that for 1907[1]; but the comparative statements of thickness are new, and for permission to publish them we are indebted to the mining firms interested in the coalfield. Prof. R. W. Dron's 'Coal Fields of Scotland' and Mr. J. Brown's 'Co-relation of Ayrshire Coalfields' have proved of great assistance.

Upper Old Red Sandstone.—About 3 miles south-east of Ayr, a small outcrop of Upper Old Red Sandstone has been found in the middle of a considerable area formerly mapped as a gentle anticline of Lower Carboniferous. A little north of the Old Red Sandstone exposure, sediments of the Cementstone Group are seen dipping in a northerly direction, and there is no reason to suspect any intervening fault.

Calciferous Sandstone Series.—The Central Ayrshire facies of the Calciferous Sandstone Series is marked by a fairly strong

[1] Smith, J., and C. T. Clough, 'Summary of Progress' for 1907 (*Mem. Geol. Surv.*), 1908, p. 127.

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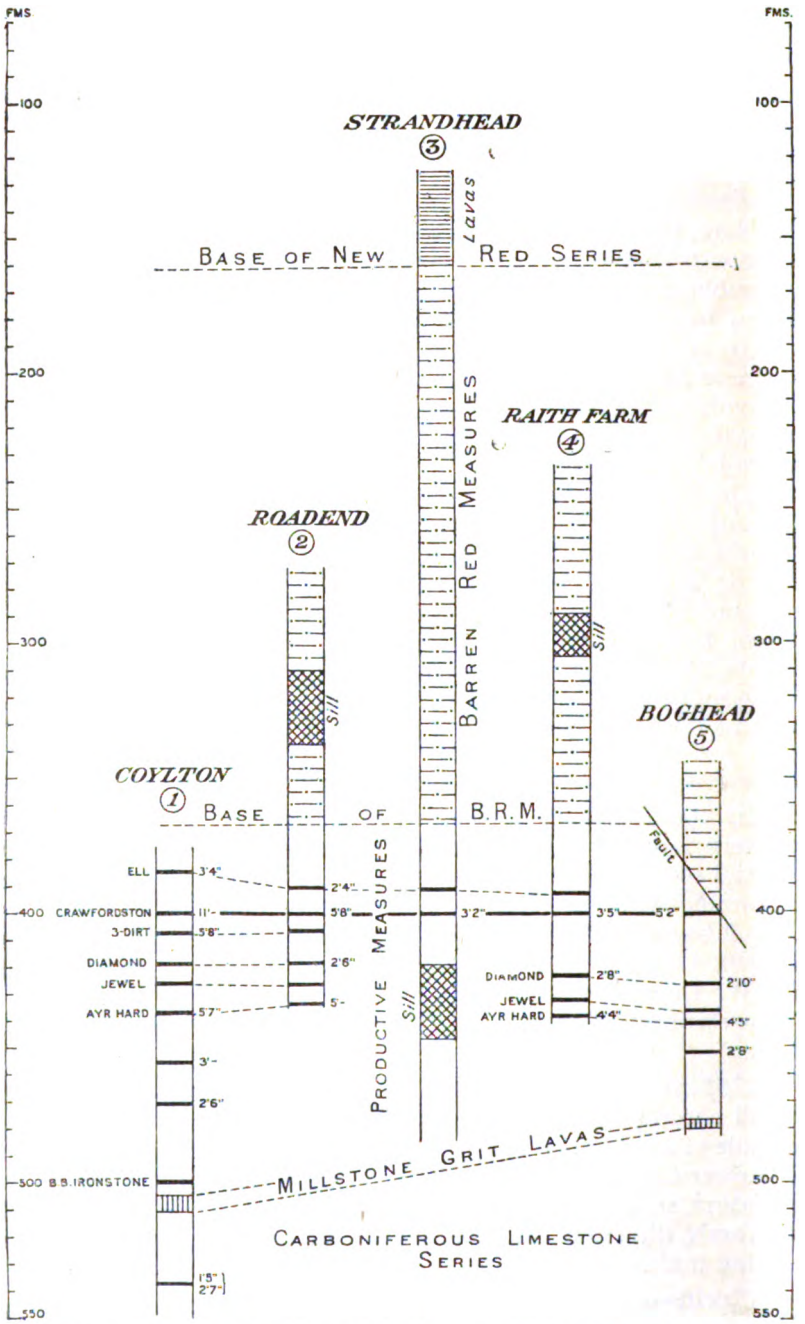

FIG. 7.—*Comparative Vertical Sections, Central Ayrshire Coalfield.*
(1) (2) & (4) *Western Area* of Text, see one-inch Map, Sheet 14.
(3) *Concealed Coalfield*, Sheet 14. (5) *Northern Belt*, Sheet 22.

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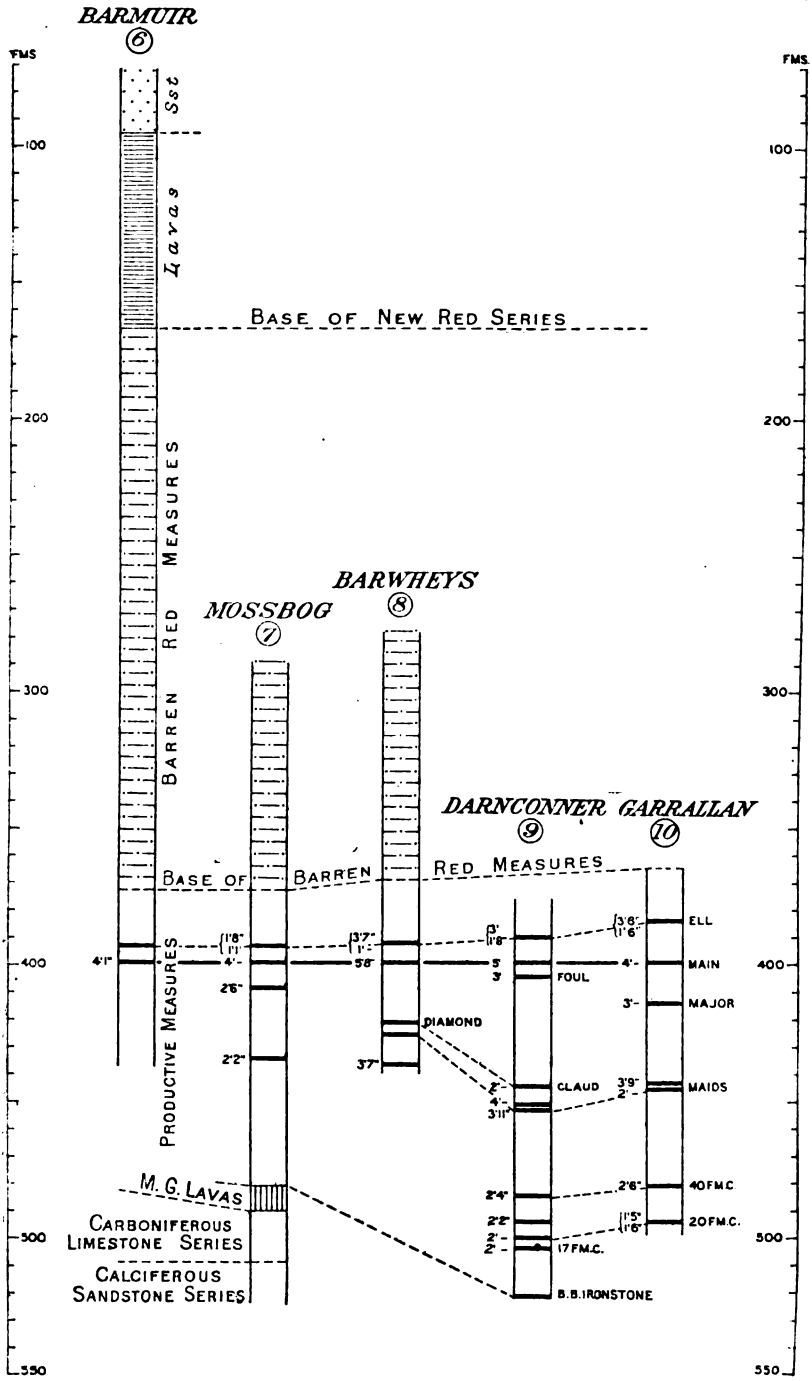

FIG. 8.—*Comparative Vertical Sections, Central Ayrshire Coalfield.* (6) *Concealed Coalfield*, Sheet 14. (7) & (8) *Northern Belt*, Sheet 14. Barwheys Farm, but not the bore, is in Sheet 22. (9) & (10) *Eastern Area*, Sheet 14.

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development of the Cementstone Group with very little to represent the Oil Shale Group of West Lothian or the volcanic rocks of the Clyde. A bore at East Doura shows only about 12 fms. of rocks between the Carboniferous Limestone Series and sediments characteristic of the Cementstone Group; and, of these, rather more than one-half consists of volcanic ash or lava-detritus. The Cementstone Group was pierced in this bore for 35 fms. without reaching its base.

Carboniferous Limestone Series.—Three bores may be cited for the information they give regarding the Carboniferous Limestone Series:—

(1) Gailes: combined thickness of Upper Limestone and Limestone Coal Groups 54 fms., with 2 ft. 4 in. coal (burnt by thin whin) 35 fms. below Millstone Grit lavas; total thickness of Carboniferous Limestone Series over 58 fms.

(2) East Doura: Upper Limestone and Limestone Coal Group 12 fms., with 9 in. coal, 9 fms., below lavas; total for series 16 fms.

(3) Mossbog: Upper Limestone and Limestone Coal Groups 15 fms.; no coal; total for series 20 fms.

Coal has been worked at only four localities along the northern outcrop of the Limestone Coal Group of the Central Ayrshire basin namely:—Smithy, west of Cairnhill House (2 ft.); two workings near March House (1 ft. 6 in. and 2 ft.); and Killoch Farm (2 ft. 6 in.).

There is little immediate prospect of profitable exploitation of the Limestone Coal Group in this part of the district.

At Sorn, a thick coal-position has been worked in the Limestone Coal Group a few fathoms below the Index Limestone. Twelve feet of coal—some inferior—is recorded, with 3 ft. 8 in. of dirt.[1] The old six-inch Geological Survey map shows the outcrop of this seam.

A mile north-north-east of Sorn on the same horizon, a pit proved 10 ft. 6 in. of coal with two sandstone partings, measuring together 6 ft. 6 in. The principal seams are gas coal 1 ft. 4 in. at 8 fms., and splint coal 4 ft. 6 in. at 10 fms. below the Index Limestone.[2]

Coal has also been worked on Weitshaw Muir, where 'Limestone' and 'Coal' are printed on the Geological Survey one-inch map, 3 m. N.N.E. of Sorn. The limestone almost certainly belongs to the Index horizon; while, a little west of its exposure, abandoned workings correspond with an old record of a 5 ft. coal 'of excellent quality,' wrought 4 or 5 ft. beneath the surface.[3] At present, a 1 ft. 6 in. coal is visible about a fathom below the limestone. If future boring confirms the existence of workable coal

[1] 'Statistical Account of Scotland,' vol. xx, 1798, p. 155.

[2] Dron, R. W. 'The Coal-Fields of Scotland,' 1902, p. 39. Mr. Dron gives this locality as about half a mile north of Sorn, but his description seems to correspond with an old 10 fm. pit near Laigh Brochlar.

[3] 'Statistical Account of Scotland,' vol. xx, 1798, p. 153.

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in the Limestone Coal Group of Weitshaw Muir, it is almost certain that the field is of sufficient extent to warrant exploitation. Mr. A. G. MacGregor has found a Coal Measures plant (*Asterophyllites equisetiformis* Schl. sp., determined by Dr. Kidston) in Cleuch Burn, half a mile S.S.E. of the coal-workings. This indicates the presence of true Coal Measures on Weitshaw Muir, where previously only the Carboniferous Limestone Series has been recognised. Though this Coal Measures outlier is not likely to contain any workable seam, except possibly a blackband ironstone, its occurrence proves the underground extension of the Limestone Coal Group. At most, the outcrop of Coal Measures is small, and is cut off on the south-east by a fault introducing pre-Carboniferous rocks in Blackside.

North-west of Sorn, there is less information, but a bore near Sorn Mains went through the Sorn coal-position and showed no seam more than 1 ft. 4 in. thick. Southwards, between Sorn and Old Cumnock, the succession does not seem to have been explored beneath the base of the Coal Measures.

Farther west the general section for Coylton (Fig. 7) shows about 38 fms. for the Upper Limestone and Limestone Coal Groups combined. The Sorn coal-position appears to be represented with three seams over 1 ft. thick; the thickest, 2 ft. 7 in., lies 26 fms. below Millstone Grit lavas.

Near Belston Farm, half way between Coylton and Ayr, a 3-ft. coal has been met with in old bores of which the records are lost. There is little doubt that it marks a continuation of the Sorn coal.

The only exposure referable to the Carboniferous Limestone Series in this south-western part of the district has been found in a small ditch lying 400 yds. west of Mill-craig Farm. Here, a short distance below Millstone Grit sediments and lavas, there are several feet of fossiliferous limy blaes, such as might be expected in the Upper Limestone Group.

Millstone Grit.—The presence of volcanic representatives of the Millstone Grit along the northern margin of the Central Ayrshire Coalfield was partially recognised during the original survey by the brothers Geikie, and much additional information has been obtained during the revision. Mr. E. M. Anderson, in last year's 'Summary of Progress,' reported that the Millstone Grit lavas are 90 fms. thick at Gailes. Three further bore-records may now be quoted:—Boghead (Fig. 7) less than 2 fms.; East Doura 15 fms. Mossbog (Fig. 8) 7 fms. The bauxitic type of weathering, with a slight development of detrital clays, has been noticed along this outcrop; but no deposits of economic value have been encountered.

South of the River Ayr, Mr. Eyles has found Millstone Grit lavas in several exposures where they had previously been treated as intrusions or altogether overlooked. These lavas are of the same general character as farther north, and have undergone weathering with formation of bauxitic clays, in part detrital

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At one locality, east of Loch Fergus, pisolitic ironstone occurs in association with the bauxitic clays, as is so often the case on this horizon. The most promising section of bauxitic clay is to be seen in a small stream between 200 and 300 yds. W.N.W. of Gateside Farm, 2 miles east of Ayr. Here, about 30 ft. of more or less bauxitic clays are overlain by Coal Measures fakes and sandstone, and grade downwards into deeply weathered lava. Analyses from three specimens taken at this locality show that the quality is poor.

The base of the lavas is exposed in a few sections showing extremely hard light-coloured sandstone (kingle) followed downwards by mottled reddish sandy fireclay and grey sandy shales, all referable to the Millstone Grit and only a few fathoms thick.

It has not been decided whether two or three of the exposures of lava in this south-western district belong to the Millstone Grit or the Calciferous Sandstone Series. This applies especially to an outcrop at Longhill Point.

In the eastern part of the coalfield, the Millstone Grit is represented mainly by sandstone, and no volcanic rocks have been recognised in the imperfect exposures available.

Coal Measures.—As elsewhere in the Central Valley of Scotland, the Coal Measures are divisible into Productive Measures and Barren Red Measures. In the Productive Measures of Central Ayrshire, coal seams are common, and some are workable. The accompanying sediments are mainly grey or light-coloured, with only very occasional red beds. In the Barren Red Measures, on the other hand, coal is practically absent, except perhaps for thin seams towards the base of the group, and the beds are predominantly red and purple.

The base of the Coal Measures is not drawn consistently throughout the district. It is taken at the top of the Millstone Grit volcanic rocks in the north-western area, extending inland to Mauchline and Coylton. East of these localities, Millstone Grit lavas are unknown, and the Coal Measures base is shifted for convenience to a blackband ironstone. Fortunately the district in which this ironstone is recognisable overlaps that in which the lavas occurs, and it can be shown that the change of datum has little significance. Near Coylton, the Blackband Ironstone position lies about 5 fms., and at Mossbog (Fig. 8) only 1 fm., above Millstone Grit lavas.

The line between the Productive and the Barren Red Coal Measures is not so well marked, but seems generally to lie about 30 fms. above the Crawfordston Coal, which is believed to persist throughout the basin. At the Barony Pit, in the south-east part of the area, where thicknesses are at a maximum, Skipsey's Marine Band, which marks the base of the Barren Red Measures in many parts of Scotland, has been recognised 46 fms. above the Main (Crawfordston) Coal. The thickness of the Productive Coal Measures is about 110 fms. in the north, 130 fms. in the south-west, and 160 fms. in the south-east.

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The thickness of the Barren Red Coal Measures possibly varies owing to unconformity at the base of the lavas of the New Red Series. Only two bores penetrate the whole of the Barren Red Measures. That at Barmuir (Fig. 8) gives a thickness of about 208 fms. for the group.

The centre of the basin beneath the New Red Sandstone and lavas is completely unworked, and includes the most important reserves of the district. Very little coal has been wrought along the northern and southern margins of the basin within the limits of the district here considered, so that most of the information comes from the western and eastern sides.

The following table suggests correlations.

Central Ayrshire.		Kilmarnock District.
Western Area.	Eastern Area.	
Ell	Ell	McNaught
Crawfordston	Main	Tourha'
Three Dirt (or Major)	? Major of Garrallan	——
Diamond	——	——
Jewel	Claud	——
Ayr Hard (or Splint)	Maid and Low Maid	Hurlford Main

In the Western Area, the most prolific portion lies between Coylton and Annbank. Special features of this district are :— in the neighbourhood of Coylton, workable ironstone near the base of the Coal Measures and moderately thick coal seams below the Ayr Hard ; and, everywhere between Coylton and Annbank, a strong development of the Three Dirt, Crawfordston and Ell Coals.

The Roadend Farm section (Fig. 7) only gives information of the succession down to the Ayr Hard. The Three Dirt Coal ceases to be workable a little south of this locality, and the Crawfordston and Ell Coals are definitely thinner than at Coylton.

Near Ayr, not much is known of the succession except that the Ayr Hard has been extensively worked. Northwards from Ayr, the other seams are known to deteriorate, and, at Prestwick, the Ayr Hard, about 4 ft. 6 in. thick, is the only one of importance.

East of Prestwick, as the New Red lava escarpment is approached, the succession becomes richer in coal, though not to the same extent as towards Coylton. This change is illustrated in the Raith Farm bore (Fig. 7). The worked seams in this district are the Ayr Hard, Diamond, and Crawfordston.

North of Prestwick, in a somewhat extensive area, there has been very little boring, with disappointing results. A bore on the coast south of Troon seems to start in Barren Red Measures and reach what may be the Troon Harbour sill. It shows a possible

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representative of the Crawfordston Seam with 2 ft. 3 in. of coal separated by partings. Another bore, starting in the Troon Harbour sill, finishes in a thick whin (not examined by the Survey), which is interpreted as Millstone Grit lava. This bore meets with no coal more than 9 in. thick. In combining these results, it must be remembered that the Troon Harbour sill is probably transgressive, and there is no certainty that the two bores (even apart from possible faulting) give a complete section of the Productive Measures. It is unlikely, for instance, that the Ayr Hard has diminished beyond recognition in the Troon district. A coal supposed to represent this seam was worked on a small scale near Collenan, 2 miles north-east of Troon.[1]

In the northern belt from Symington to Barwheys coal has only been wrought in shallow pits at Adamhill Farm, and at Hill and Roughdyke Farms on the two sides of the railway farther east. The seam appears to be the Crawfordston, about 5 ft. thick. At Adamhill, it was known as the Gas Coal, 4 ft. thick, but the Boghead bore (Fig. 7) shows the Crawfordston Coal with only 9 in. of gas coal in a total 5 ft. 2 in.

The Boghead bore shows a 2 ft. 8 in. coal, 12 fms. below the Ayr Hard. The latter seam in this bore is 4 ft. 5 in. thick. The Jewel is 1 ft. 1 in., but in a neighbouring bore at Lochlee it measured 2 ft. 6 in. The Diamond at Boghead is 2 ft. 10 in. The position of the Ell seems cut out by faulting, but the Lochlee and Barmuir bore show that it does not exist in workable condition hereabout.

Farther east, the Mossbog bore differs from those at Boghead and Lochlee in not showing any workable seam below the Ayr Hard, or any appreciable representatives of the Jewel and Diamond Coals. The Ayr Hard is thin (2 ft. 2 in.), but a possible representative of the Three Dirt or Major is 2 ft. 5 in. The principal coal here, as in most of this northern district, is the Crawfordston, 4 ft. thick. As at Lochlee, the Ell is a divided seam, of which the thickest member measures 1 ft. 8 in.

In a couple of bores east of Mossbog (No. 2 Crosshands and Craighead) the Ayr Hard has been proved with thicknesses 2 ft. 8 in. and 5 ft. 7 in., and the Jewel, or some similarly placed coal, 1 ft. 8 in. and 1 ft. 1 in. The Crawfordston in the No. 2 Crosshands bore is 4 ft. 9 in. thick.

At Barwheys, the Ayr Hard is 3 ft. 7 in. thick, with, as often, 'mussels' above it. The Jewel, Diamond, and Three Dirt or Major, all appear to be represented, though worthless. The Crawfordston is 5 ft. 8 in., and the Ell contains 4 ft. 7 in. of coal with a 1 ft. 2 in. fireclay parting.

In the Eastern Area, three bores put down near Sorn Mains, N.W. of Sorn, indicate the presence of a coal 4 ft. 8 in. to 6 ft. 11 in. thick. There is a prevalent impression that this coal must be in

[1] Anderson, E. M., 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 82.

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the Limestone Coal position, but it has been shown[1] that such is not the case. Probably the seam is the Ayr Hard.

South of the Ayr, the coals have been extensively worked in the outcrop of the Productive Measures, but only a beginning has been made in following them below the Barren Red Measures. As indicated in the Table (p. 99), the naming of the coal seams differs from that employed in the west.

The Blackband Ironstone at the base of the succession has been very extensively wrought in the past. The coals below the Maids have only been worked on a small scale, and are not worked at present. They have a tendency to vary in thickness, and become worthless. The 17 fm., 20 fm. and 40 fm. seams are the most constant. The Maids, Main, and Ell have all been largely worked, especially the Main, which is an excellent household coal.

Farther south, towards Garrallan, the Main (4 ft.) and the Ell (3 ft. 6 in.) are the only coals extensively worked on the south side of the line of the Steep Metals, except at Garrallan Colliery itself. Here, the Maids (3 ft. 9 in. and 2 ft.), Claud (2 ft. 8 in.) and Major (3 ft.) are all wrought, although the Claud is not shown in Fig. 8.

In the southern area west of Garrallan, very little has been done to exploit the coals under the Barren Red Measures, except at Drumsmudden Pit, now abandoned. Here, the Main, including 9 ft. of coal with a 1-ft. parting, was much worked, and the Ell (3 ft. 6 in.) to a less extent. The depth of the Main Coal in the shaft was 202 fms.

The *Concealed Coalfield* of the basin may be defined as the Coal Measures, 28 square miles in extent, that lie concealed beneath New Red lavas and sandstones. As yet no coal has been worked within its limits. The preceding account makes it tolerably certain that the whole of the district is underlain by two coals of workable thickness: the Crawfordston (or Main) may be expected to be about 4 ft. thick in the north and to increase towards the south; the Ayr Hard (or Maids) to be 4 ft. thick in the northern half and 5 ft. in the southern half of the field. These two coals are about 37 fms. apart; the distance increases towards the south-east. In the south, the Ell Coal, from 2 to 3 ft. thick, may be expected about 13 fms. above the Crawfordston.

Only two bores have reached the coals of the concealed basin. At Strandhead, the Crawfordston was found 3 ft. 2 in. thick. At Barmuir, the same seam measures 4 ft. 1 in. For some reason both bores failed to prove the Ayr Hard, although the Strandhead bore at any rate, went sufficiently deep. This failure does not materially weaken the general conclusion that the Ayr Hard persists throughout the district. The depth of the Crawfordston Seam below the base of the New Red Lavas and ashes in the two bores is 240 and 235 fms. Considerably greater depths may be expected towards the south-east end of the basin.

[1] Simpson, J. B., 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, p. 76.

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Only two bores, one at Barmuir and the other at Auchinweet, have pierced the full thickness of the New Red lavas and associated ashes. The Barmuir record shows these volcanic rocks to be 73 fms. thick, while the Auchinweet gives 86 fms. This means that the Crawfordston Seam may be expected about 320 fms. below the top of the volcanic group.

At Auchinweet, 115 fms. of New Red Sandstone were pierced before reaching the New Red volcanic group. At Middleton Hill, a bore proved 170 fms. of sandstone in this position. It is probable therefore, that the Crawfordston Seam is about 500 fms. deep at Middleton Hill. At the centre of the basin, about Stairaird, the depth may approach 600 fms.

Faults.—Three recent advances in regard to the structure of the Central Ayrshire Coalfield may be mentioned on account of their economic bearing.

(1) A north-west fault, with a large downthrow to the south-west, runs near Barmuir. This fault has already been dealt with in detail,[1] and it is only necessary to add that it is uncertain at present which side of Barmuir it passes.

(2) Mr. A. B. Garvin has drawn our attention to another considerable fault which almost certainly runs east from the Barmuir fault and forms the northern limit of the New Red lavas past the Mossbog bore. The downthrow is to the south.

(3) Further information has been obtained in relation to the belt of Steep Metals in the south-eastern corner of the district.

In the Steep Metal belt, the strata are tilted up 60° or more, and their disturbance has proved an effective bar to working except at Lugar Railway Station. Here, the trouble is least marked, and the coals, flexed into a narrow steep syncline, have been successfully worked across the belt.

As a rule, mining plans show the Steep Metals persistently dipping N.W., but Mr. Wilson claims that, where this is the case, the flexure is accompanied by a fault which, throwing down to the S.E., generally more than compensates for the north-westerly dip. Between Lugar Station and Old Cumnock, he has estimated the net result of the disturbed belt as a downthrow of 50 fms. to the S.E.[2]

South-west of Old Cumnock, there is an extensive unworked area north-west of the Steep Metals, and it is generally assumed that the coals lie much deeper here than in the worked area on the south-east. There is, however, good evidence to the contrary. Coal is exposed at the surface at two points near Grimgrew Farm a little north-west of the line of Steep Metals encountered in mining operations. It is almost certain that these correspond to one or more thin seams not more than 40 fms. above the Main (Crawfordston) Coal. This encourages the view that a large field of

[1] Eyles, V. A., 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, p. 76.
[2] Wilson, G. V., 'The Iron Ores of Scotland' (*Mem. Geol. Surv.*), 1920, p. 46.

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moderate depth awaits exploitation north-west of the Steep Metals.

The course of the Steep Metals cannot be traced with certainty at the surface owing to much of the district being covered by boulder-clay. Steep metals are, however, seen in the stream east of East Grimgrew Farm, and two miles farther south-west in the Burnock Water. It is uncertain whether these exposures represent the main line of the Steep Metals or a parallel branch a little farther north-west. The coal outcrops already mentioned occur on the north-west side of the exposed disturbance.

Intrusions.—The Coal Measures of the western part of the field have been intruded into by great transgressive sills. Near Ayr these sills lie below and above the Ayr Hard. Near Prestwick, a thick sill of the group is met with above the Crawfordston Coal, and can be followed in bores and natural sections to Stair on the River Ayr, where it seems to split and send a branch below the Three Dirt Coal. Farther north again, in the coastal district, the Meikle Craigs sill, south of Troon, corresponds with the Prestwick sill, though it has reached a slightly higher horizon; while the Troon Harbour sill probably lies near the position of the Ayr Hard Coal.

It is possible that, locally, the coals of the concealed coalfield may be ruined by sills.

E. B. BAILEY.

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2. MUIRKIRK, COALBURN, STRATHAVEN AND THE CENTRAL COALFIELD

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E. M. ANDERSON, M.A., B.Sc., Senior Geologist.
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J. PHEMISTER, M.A., B.Sc. } Geologists.

Field-work was carried on during 1923 in the north-western corner of one-inch Sheet 15 and in the central and western portions of one-inch Sheet 23. Mr. E. M. Anderson continued the revision of the Downtonian, Old Red Sandstone and Carboniferous rocks of the Muirkirk-Cronberry district in Sheet 15. In Sheet 23 the re-examination of the ground between Ponfeigh and Auchlochan was completed by Mr. G. Ross; and Mr. J. Phemister has re-mapped a considerable area of Calciferous Sandstone volcanic rocks along the western margin. Both in the Muirkirk and Auchlochan areas much new mining information was obtained during the revision. Mr. W. Manson was detailed for part of the field season to collect material from the Lower Limestones of Glenbuck, Bankend and the River Nethan near Stockbriggs, with a view to establishing a definite correlation between these areas. The results of this investigation are given below by Messrs. Ross and Manson. In the Central Coalfield a number of important borings were visited and examined. Much valuable scientific information that would otherwise have been lost has thereby been secured and our thanks are due to the colliery companies concerned for their generous co-operation.

The Memoir on 'Economic Geology of the Central Coalfield, Area VI.', was completed and printed and the preparation of second editions of the 'Geology of the Glasgow District' and the 'Economic Geology of the Central Coalfield, Area V,' commenced.

MUIRKIRK COALFIELD

Downtonian and Old Red Sandstone.—The surface examination of the Muirkirk Coalfield has now been nearly completed, and Mr. Anderson has mapped the small Wellwood basin of Coal Measures and the Gass Water area of Limestone Coals. He has also surveyed a part of the Downtonian and Old Red Sandstone area of the Greenock and Whitehaugh Waters, and reports that the area of Downtonian rocks in this district is probably somewhat less than was previously supposed. A hitherto unrecorded outcrop of volcanic tuff and agglomerate, with some lava, occurs near Nether Whitehaugh. The igneous rocks probably belong to the Lower Old Red Sandstone, and may be faulted against Downtonian strata.

Upper Limestone Group.—An important addition to our knowledge of this group has been made by Mr. Anderson, who reports that a limestone exposed near the centre of the Glenbuck basin

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is shown by mining evidence to lie 30 or 40 fms. above the Blue Tour Limestone. If this higher seam corresponds, as seems likely, with the Castlecary or Levenseat Limestone, the total thickness of the Upper Limestone Group in the Muirkirk basin must be 100 fms. or slightly more. A limestone seen beside the Proscribe Burn, west of Muirkirk, is probably on the same horizon.

The Blue Tour Limestone has generally been regarded as the equivalent of the Calmy Limestone. *Edmondia punctatella* (Jones), the fossil which characterises the under side of the Calmy throughout the Central Coalfield, as well as in Ayrshire and West Fife, has not so far been noted in the blaes below the Blue Tour, although it has recently been obtained in the Garpel Water 80 ft. below the Blue Tour at the base of a thick post of fossiliferous calcareous shales.

Glacial.—Mr. Anderson has mapped two marked glacial marginal channels, which cross the watershed between the Gass Water and the River Ayr, a mile and a half west of Wood Hill. The drainage is to the north-east. Both these channels and those recorded by Mr. Wilson several miles to the north,[1] seem to be marginal to the nose of a glacier, which was pressing into the Muirkirk-Douglas valley from the west.

Strathaven

Lavas.—Revision of the Calciferous Sandstone lavas forming the high ground between East Kilbride and the River Avon was continued by Mr. Phemister, who reports that the lavas are mostly olivine-basalts with some Markle basalts and trachytes. In the burn flowing past Cleuchearn Lodge lavas of a type intermediate between basalt and trachyte, sometimes with phenocrysts of hornblende fully 1 cm. in length, were observed. Another apparently intermediate type, which in the hand specimen resembles trachyte rather than basalt but carries pseudomorphs of ferrite after olivine, is seen in an old quarry two hundred yards north of Hairshaw Farm. These rocks have not yet been examined microscopically. Volcanic agglomerate containing trachyte bombs is excellently exposed, interbedded with basalt, in the burn three quarters of a mile west of Hairshaw, and near the River Calder half a mile north-west of Hairshaw.

So far no sequence of lava flows has been determined which holds good over any considerable area, and owing to the absence of terrace features, and to the presence of extensive coverings of boulder clay, gravel, and peat, accurate correlation is impossible.

Glacial.—South of Chapelton occur several kame-like ridges and many low gravel mounds (mapped by Mr. Dinham). Farther west a gravel ridge can be traced from Cladance Farm to about one quarter of a mile west of Cleuchearn Lodge, where it dies out abruptly. The ridge always presents a steep face to the

[1] 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, pp. 80-81.

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flat ground on the north, but on the south may pass with little or no slope on to the boulder clay, which covers the gentle ascent on the south. At Skeoch Farm the wall-like ridge is replaced by several low mounds. The flat ground on the north side is covered partly by gravel and partly by peat, and occasionally contains gravel mounds elongated parallel to the main ridge. It is very wide at Cladance, but narrows to three or four hundred yards where the ridge disappears west of Cleuchearn Lodge. At this position it is noteworthy that gravel mounds occur also on the north side of the flat and low mounds occur within it. The flat is now drained by several burns which flow northwards into the Calder Water, but it is clear that at one time the drainage northwards was choked.

Reference is made to the ridges, mounds and flats of gravel at Cleuchearn, Cladance and Chapelton by Geikie,[1] who considers that they are the equivalent of the terraces at Eaglesham and that thay have been deposited by torrents running between the hill slope on the south, and the *mer-de-glace* on the north, the ridges being formed where the passage was narrow and the flat gravel spreads where there was a wide area between the hill slope and the margin of the ice sheet. But as the ridges actually occur where the flat is wide there is need for some other explanation. It may be suggested that they are due to fragments of the ice-sheet left stranded on the flats, the sand and gravel being deposited in the channels between these and, on the melting of the ice, standing out as mounds and ridges.

Exactly on the western margin of the map just south of High Huntlawrig Farm is a striking gap or dry channel fully 150 yds. long, with an average width of 40 or 50 yds. The gap opens out on the east into a channel floored by subdued knobs of disintegrating rock, Widening eastwards and northwards this channel debouches on the rolling spread of sand and earthly angular gravelly drift south of Bethern and Raahead Farms. To the west of the gap (in one-inch Sheet 22) is a peaty flat probably formerly occupied by a glacier-fed loch. Apparently the drainage of this loch cut the gap, bared the rock in the channel, and deposited the earthy drift, which corresponds exactly to a wash from a mixture of boulder clay, sand, and disintegrated rock. This belongs to the final stages of the Glacial history of the district, and is probably later than the deposition of the sand and gravel mounds and flats of Cleuchearn.

Glenbuck and Coalburn

Lower Limestones.—A comparison of the Lower Limestone sequence at Glenbuck and Bankend has yielded several points of interest. The sections (Fig. 9) show, in addition to the Lower Limestone Group, small portions of the Limestone Coal Group and

[1] 'The Great Ice Age', 1894, p. 177.

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of the Calciferous Sandstone Series. Mr. Manson has collected material in both areas and contributes the notes on the Coal Burn section at Glenbuck. The exposures in the Poneil Water and Hagshaw Burn near Bankend[1] were examined by Mr. Macgregor and Mr. Manson, and Section 2 (Fig. 9) is based on their field-work.

In both areas the marine horizon known as the Johnstone Shell-bed is well developed and with the underlying Macdonald Coal forms an easily recognisable index-horizon. This shell-bed consists of several feet of shales (blaes) with abundant *Producti* and other marine organisms and passes upwards into shales containing scattered *Lingula*. The Macdonald Coal, on which it rests, occurs typically in two leaves separated by a few inches of fireclay. A few fathoms below the coal come the Macdonald (or Hosie) Limestones, three or four in number and below these the limestones described as limestones A, B and C. The two sections show clearly that the general sequence is much the same in both areas and the correlations given are supported by the detailed lithological and faunal evidence.

Limestone A in the Glenbuck district is a solid post of grey limestone with a faint brown or reddish tinge, and varies in thickness from 2 ft. 6 in. to 2 ft. 10 in. *Productus giganteus* is present in it, but complete specimens are difficult to extract from the matrix. This seam at Bankend in the Coalburn field is 10 ft. thick, flaggy and pale grey on weathering. The lamellibranch *Syncyclonema sowerbyi* occurs here in great abundance. In the Hagshaw Burn (640 yds. from its mouth) the limestone is more solid than elsewhere in the neighbourhood and contains *Productus giganteus* (mut.). In both districts Limestone A. is overlain by fireclays separating it from the Macdonald Limestones and underlain by richly fossiliferous dark shales, in which the characteristic fossil is a lobate form of *Productus longispinus*.

Limestone B in the Glenbuck area is 18 to 20 ft. thick and is composed of alternating beds of hard grey limestone and calcareous shales. The highest post of limestone is white with a nodular top. In Coalburn good exposures of it are seen in the disused Bankend Limestone Quarry. The limestone is about 40 ft. thick; in its upper portion are several fairly solid beds passing down into thinner irregular bands of hard limestone with calcareous shaly partings. A sandstone with an average thickness of 5 ft. overlies Limestone B at Bankend and Glenbuck. At Glenbuck it is soft but in the Bankend Quarry its upper 2 ft. is a hard white ganister-like rock with a nodular top.[2] Resting on the sandstone is a thin rib of clayband ironstone locally reaching 14 in. at Glenbuck (Crossflat Ironstone). These two beds, the Crossflat Ironstone and the underlying sandstone, persist throughout the areas under consideration and are important in elucidating the sequence. In both areas again Limestone B is closely underlain by a 4-in. to

[1] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, pp. 52–55.
[2] 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, p. 54.

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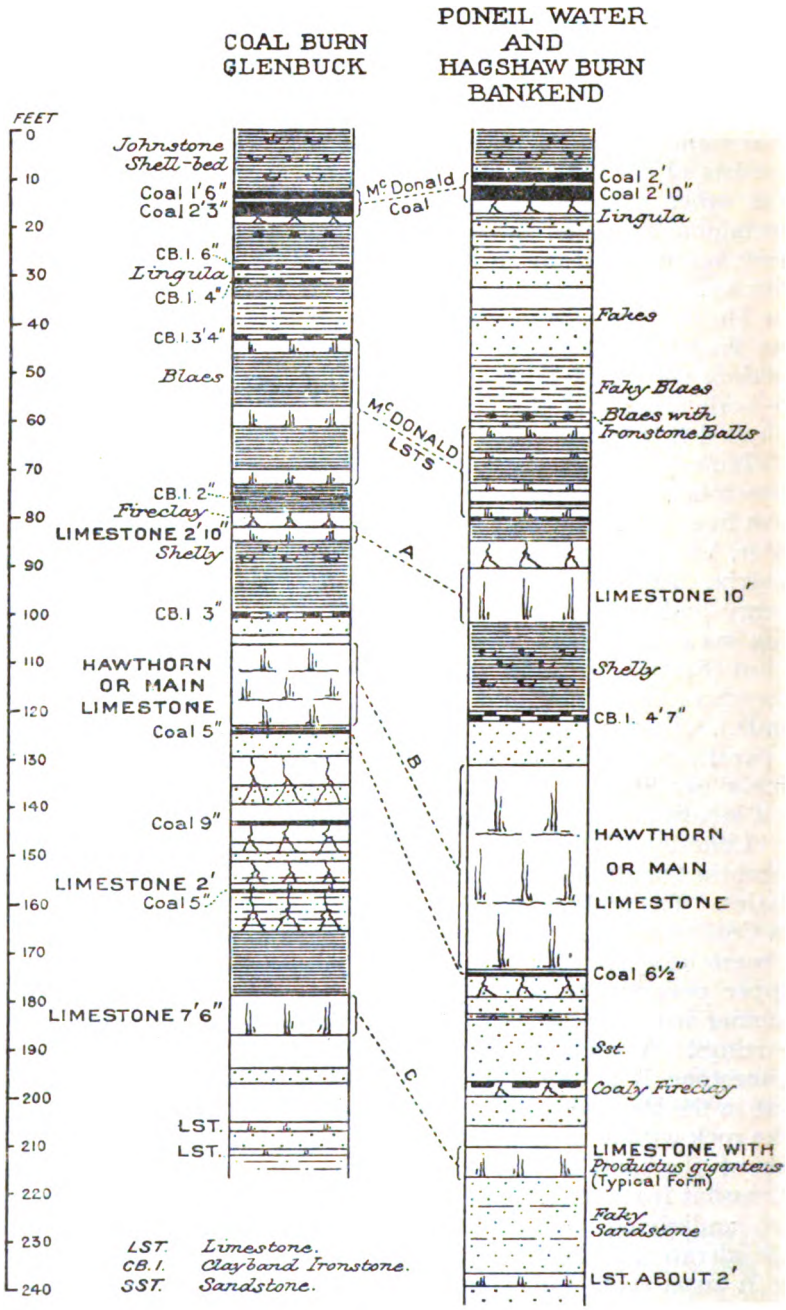

FIG. 9.—*Vertical Sections at Glenbuck and Bankend.*

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6-in. coal resting on fireclay. Among other fossils *Productus giganteus* (mut.) occurs in the Glenbuck and Bankend outcrops and the peculiar form of this Productid, 'evincing catagenetic loss of the furrows in the umbonal region,'[1] as compared with the form in the underlying Limestone C, may be considered of zonal value.

Limestone C in the Bankend district has long been known as the *Productus giganteus* Limestone. Its upper part is composed of nodules of white limestone in a sandy matrix; its lower part consists of dark limestone and calcareous shales. It is 4 ft. thick where seen near Brockley and 6 ft. in the higher part of the Hagshaw Burn. At Glenbuck the same bed shows 15 ft. of shaly limestone and limestone ribs resting on 4 ft. of solid grey limestone. The *Productus giganteus* (Mart.) that occurs at this horizon is a form showing marked furrows in the umbonal region becoming deeper as they extend over the surface of the shell while the form characteristic of the higher limestones B and A shows (as already noted) catagenetic loss of the furrows in the umbonal region. Limestone C is also the first limestone containing *Productus giganteus* that occurs below Limestone B.

In the 'Summary of Progress' for 1922[2] a brief reference was made to the limestones exposed in the faulted ground along the River Nethan between Old Stockbriggs and Stockbriggs House. It is now possible to assign these to a more definite stratigraphical horizon. The highest of the three, exposed in the east bank of the Nethan nearly midway between Stockbriggs House and Old Stockbriggs, where it dips 20° N.E., shows 11 ft. of rather flaggy limestone with alternating beds of very fossiliferous shale in which *Syncyclonema sowerbyi* is specially abundant, along with *Ambocoelia urei*. It is overlain by several feet of grey fireclay, but the base is not well exposed, nor is anything seen of the underlying beds. This limestone is comparable with Limestone A of the Bankend section.

The exposure of the 'Wee' Limestone of Auldton, which occurs about 200 yds. upstream, dipping N.N.E. at about 18°, shows nearly 8 ft. of solid dark grey limestone with a nodular richly fossiliferous layer of about 8 in. at the base, and a 6-in. coal below, resting on a thick bed of fireclay. It is overlain by about 8 ft. of hard calcareous shales followed by about 4 ft. of sandstone, on which rests a clayband ironstone 7 in. thick. The 'Wee' Limestone evidently corresponds to Limestone B of the Glenbuck and Bankend sections.

The outcrop of the 'Big' Limestone of Auldton, which occurs about 160 yds. upstream, shows nearly 8 ft. of limestone and limy shales including near the base a solid *Lithostrotion* bed about 3 ft. thick. This limestone yields specimens of *Productus giganteus* of

[1] Lee, G. W., 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 123.
[2] p. 87.

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the type found in Limestone C of the Bankend and Glenbuck sections, and its lithological character and position—probably about 10 fms. below the 'Wee' Limestone—further serve to identify it with that limestone.

The thinning out northwards of Limestone B is confirmed by sections at Auldton and Auchren Limeworks and by bores in the neighbourhood of Auchmeddan. In these sections the 'Wee' Limestone averages 4 ft. in thickness and is overlain by several fathoms of limy shales. The thin coal and the underlying fireclay are invariably present. Here it is separated from the 'Big' Limestone by about 7 fms. of strata, the succession being:—

	Ft.
'Wee' Limestone and Coal	4
Fireclay	6 to 12
Sandy fakes and blaes ... ... about	10
Sandstone ... ... ,,	6
Limy fakes and blaes with a white limestone rib about 1 foot thick near the base	6 to 7
'Big' Limestone	10 to 11

Central Coalfield

Limestone Coal Group.—Borings put down in recent years at different localities in the Central Coalfield have added considerably to our knowledge of the occurrence and character of the marine horizon known as the Johnstone Shell-bed. The bed has now been proved at a large number of places throughout the coalfield and may be regarded as a well-marked and constant unit in the Limestone Coal Group succession from Glasgow and Paisley eastwards to Bathgate, Wilsontown and Carluke.[1] From a mining point of view it is of importance as being the first marine horizon to be encountered below the Kilsyth Coking Coal, the lowest workable coal of the Limestone Coal Group. It lies a few fathoms under this seam, and in faulted ground or in areas where the coal is thin or difficult to identify its presence indicates the limit beyond which it is useless to bore.

Fig. 10 (p. 111) illustrates the sequence from the Black Metals to the Top Hosie Limestone at four points within the Central Coalfield, and shows that between the base of the Black Metals and the Johnstone Shell-bed there are several seams of which the Kilsyth Coking Coal is the most important. The Black Metals are readily recognised in borings by their character and contents. They consist of a thick series of shales (blaes) with numerous ribs (*e.g.* the California and Banton Ironstones), and balls of clayband ironstone. In the Glasgow district *Lingula*, *Orbiculoidea* and Rhynchonellid fragments have been obtained from these shales, but few opportunities of examining them in detail have been offered. All over the Central Coalfield to the east of Glasgow, however, there is

[1] It occurs also in Ayrshire and the Douglas Coalfield; see, for example, p. 107 and Fig. 9.

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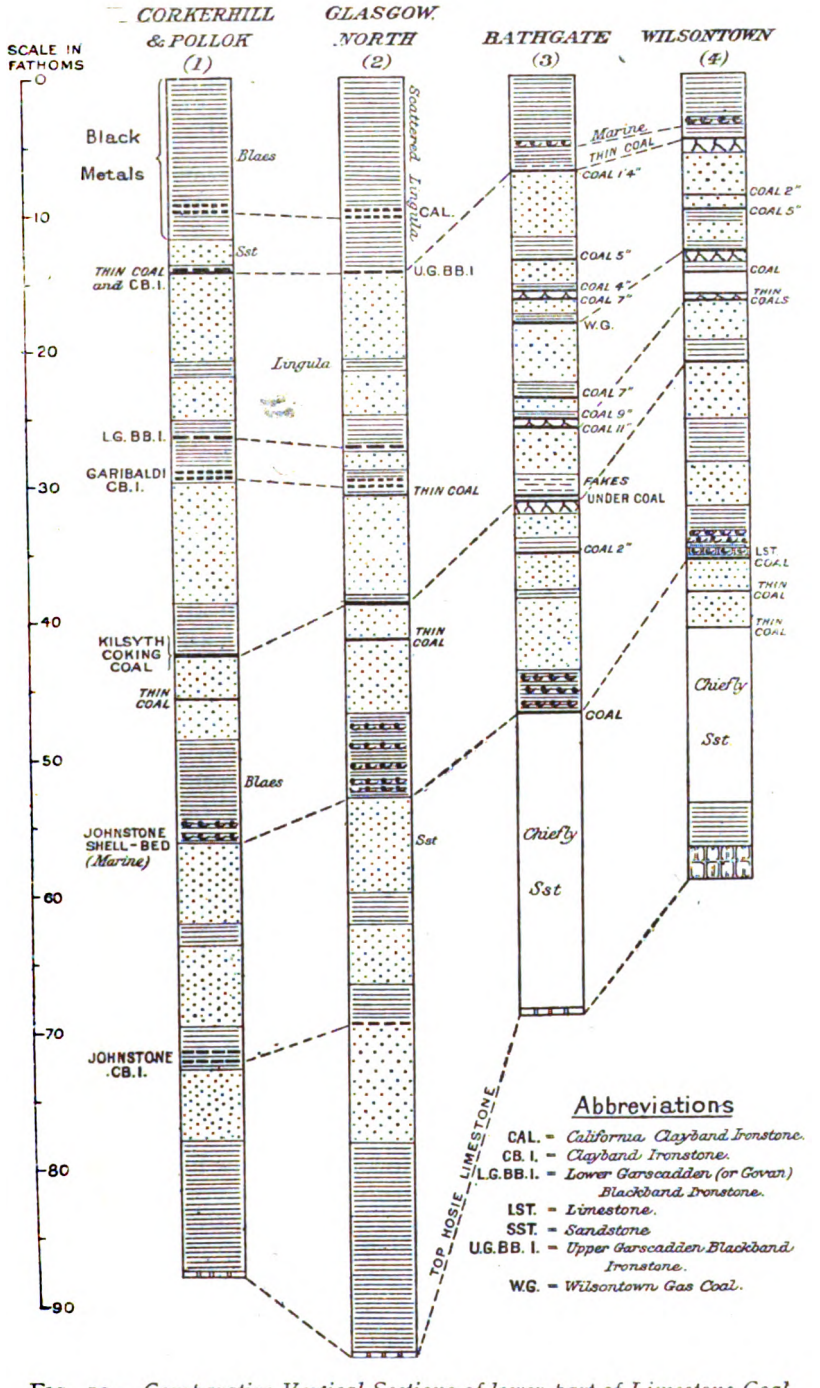

FIG. 10.—*Comparative Vertical Sections of lower part of Limestone Coal Group, Central Coalfield.*

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a definite band of marine shells in the lower part of the shales, while very often a layer of estuarine lamellibranchs ('mussels') has been observed a few feet higher. The Black Metals with their marine band thus forms a valuable index to the coals and ironstones which lie between them and the Johnstone Shell-bed. The latter consists of several feet of more or less fossiliferous shales, the lower part of which is crowded with shells and passes locally into a fairly solid impure shelly limestone (Fig. 10, Section 4). The Kilsyth Coking Coal in the Glasgow area is from 1 to 2 ft. in thickness, but increases in a north-easterly direction towards Garnkirk, Auchengeich and Kilsyth. Along this north-western margin of the Lanarkshire Basin it attains its maximum development and can always be readily identified in borings, but in other areas where the Limestone Coal Group is markedly thinner definite correlation is not always easy or even possible. Along the eastern outcrop of the Carboniferous Limestone Series between Bathgate and Wilsontown (Fig. 10, Sections 3 and 4), the Coking Coal is most probably represented by the seam known as the Under Coal from the fact that it was worked to a small extent at Haywood under this name. The Wilsontown Gas Coal of the same area would thus be on the same, or approximately the same, horizon as the Lower Blackband Ironstone of Glasgow (Section 2). This blackband passes laterally into a coal, reappearing as an ironstone in the Kilsyth area (the Banton Blackband), and it may be noted that a rib of blackband locally accompanies the Wilsontown Gas Coal. Along the southern edge of the Lanarkshire Basin, from Carluke to East Kilbride, the Limestone Coal Group shows marked attenuation as compared with the Glasgow, Kilsyth and Bathgate areas[1] while the associated coals are fewer and, in general, thin. Here again, however, the Black Metals and the Johnstone Shell-bed are readily recognised in borings, so that while it would be difficult to identify any particular seam as the equivalent of the Kilsyth Coking Coal it is possible to refer it to one of a group of coals lying very close together. In the East Kilbride area, for example, the Kilsyth Coking is clearly represented by one of the Crutherland seams.

The two marine horizons briefly referred to above will undoubtedly be of the utmost value wherever attempts are made to prove the Kilsyth Coking Coal in the concealed areas of Limestone oals underneath the Millstone Grit and Coal Measures of the Central Coalfield. Borings should be carried down to the Johnstone Shell-bed if there is any dubiety regarding the interpretation of the sequence. The thoroughly marine character of this bed is shown by the following list of fossils obtained from a boring in the Glasgow district:—

(*a*) From the upper part of the shell-bed:—*Naiadites magna*

[1] About 414 ft. at Carluke, 318 ft. at Auchenheath, 480 ft. at East Kilbride, as compared with approximately 930 ft. in the Glasgow district and about 670 ft. at Bathgate.

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Hind ; *Lingula mytiloides* J. Sow. ; *L. squamiformis* Phill. ; *Nucula gibbosa* Flem. ; *Protoschizodus axiniformis* (Portlock) ; Pectiniform shell ; fish scales.

(*b*) From the lower part :—Crinoid ossicles ; *Schizophoria* ; *Sanguinolites* cf. *omalianus* de Kon. ; *Orthoceras cylindraceum* Flem. ; *Camarotoechia* cf. *pleurodon* (Phill.) ; *Edmondia laminata*, var. *sublaevis* Hind ; *Aviculopecten* ; *Productus sp.*, fine ribbed and spinose.

M. MACGREGOR.

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3. FIFE AND KINROSS

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In the revision of this coalfield, Mr. Haldane carried eastwards his previous work in Clackmannanshire (one-inch Sheet 39), and has surveyed an area on the western margin of Sheet 40 between Culross and Saline. Mr. Dinham started work in the neighbourhood of Dunfermline, and to Mr. Allan was assigned the country around Cowdenbeath, from Aberdour to Kelty. Each officer has further surveyed a small portion of the Fife coast lying in Sheet 32 but immediately adjacent to their several areas. Mr. Knox joined near the end of the field season and was stationed at Cowdenbeath for training.

The strata surveyed range from the base of the Coal Measures to the upper portion of the Calciferous Sandstone. The general dip is toW.N.W., but is so extensively modified by subsidiary folding that the structure of much of the ground, where the drift cover is thick and boring records few, is exceedingly problematical. The larger anticlines lie 2 m. S.E. and 2½ m. N. of Dunfermline. On the east side of these a well-marked syncline extends N.N.E. from Inverkeithing by Fordel and west of Cowdenbeath to the east of Benarty Hill, diversified by minor troughs and anticlinal ridges elongated in the same general direction. On the west where the minerals have been less thoroughly explored, the structure is not so clear, but seems likely to be no less complicated. Throughout the district numerous faults, with a predominant W.N.W. trend, cut across the folds at right angles and produce further irregularities in the outcrops of all the seams.

Calciferous Sandstone Series: Oil Shale Group.—In the ground lying north-west of Aberdour Mr. Allan finds that the chief exposures consist of massive sandstones, which are being quarried for building and monumental stone of good quality and contain plant remains of Lycopod and Conifer type. At the Cullalo cutting, on the Cowdenbeath-Burntisland road, a good section was obtained below one of the doleritic intrusions, here 200 ft. thick. It shows about 50 ft. of shales (blaes and fakes) with barren limy and pyritous ironstones, resting on 118 ft. of sandstone. The shales are baked and bleached for a distance of about 5 ft. from the sill, above which an encrinital limestone has been quarried which probably lies at or near the top of the series.

In the Dunfermline area, strata belonging to this series outcrop on the shore between Limekilns and Inverkeithing, and have been partly described by Mr. Maufe. Inland, nothing is seen of these rocks beyond a few exposures of sandstone near Mastertown (2 m. S.E. of Dunfermline) and Balmule (2½ m. N.). No bores, so far as

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is known, have penetrated more than a few fathoms into these strata, and the presence or absence of workable seams of oil-shale between Dunfermline, Rosyth and Inverkeithing, as well as in the country north-west of Aberdour, remains to be proved.

Carboniferous Limestone Series: Lower Limestone Group.—In the ground surveyed by Mr. Dinham considerable additions have been made to our knowledge of the Lower Limestones of West Fife. The full sequence has for the first time been established, the results of a partial revision of the Charlestown and Dunfermline area by Mr. H. B. Maufe[1] have been confirmed and extended, and, with the help of the bores recently put down by Mr. H. M. Cadell[2] east of Bo'ness, such correlations with the Central Coalfield have been made as circumstances permit.

(i) *Description.*—The Charlestown Station Limestone at the base of the Series is exposed 100 yds. S.W. of the railway station at Charlestown, and elsewhere on the shore. Inland, no exposure of this seam is known except west and south of Kiln Houses near Gask (3 m. N.N.E. of Dunfermline), where a limestone lower than the Charlestown Main seam was once quarried. (The limestone at Sunnybank, ¾ m. N.N.W. of Inverkeithing, referred to by Mr. Maufe as probably the Station Limestone, appears more likely to be the Main Limestone.) This limestone has been proved in bores near Dunfermline, about 40 fms. below the Charlestown Main, and 4 to 8 ft. in thickness.

Between the Charlestown Station and Main Limestones, and in general rather nearer to the former, is a 1 to 2-ft. encrinital bed, hitherto unrecorded except on Mr. Maufe's map, where it is noted as outcropping about 100 yds. S.S.W. of the west end of The Green at Charlestown. The same bed, however, has been met with in several bores, and is also exposed inland, 70 yds. N.W. of Gask steading.

The Charlestown Main Limestone is the thickest seam in this part of Fife. It has been wrought in nearly a score of places at one time or another, though at present only the Charlestown and Roscobie quarries are active. While it locally reaches 60 ft. in thickness, the average figure is nearer 25 ft., and even at Charlestown only 6 ft. were found at one spot. The greater thicknesses appear to be confined to the western portion of the area surveyed, and at Roscobie seem to be due, at least in part, to knoll structures similar to those of the Craven district of Yorkshire[3]; in the eastern portion the average thickness proved in bores is 7 to 12 ft. only. Above the limestone lie several fathoms of blaes, almost invariably

[1] 'Summary of Progress' for 1905 (*Mem. Geol. Surv.*), 1906, pp. 134–137.
'Geology of the Neighbourhood of Edinburgh' (*Mem. Geol. Surv.*), 1910, pp. 116, 117.

[2] H. M. Cadell, 'The Geology of the Blackness District as disclosed by recent Borings,' *Trans. Roy. Soc. Edin.*, vol. liii, pt. 1, 1922, pp. 189–207.

[3] James Wright, 'On the Occurrence of Crinoids in the Lower Carboniferous Limestones of Fife,' *Trans. Edin. Geol. Soc.*, vol. x, pt. ii, 1912, p. 154.

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accompanied by large septarian ironstone nodules and usually containing marine fossils throughout, but in especial abundance at the base. From this blaes, and probably several feet above the limestone, Dunlop obtained a long list of fossils.[1]

Another limestone, also surmounted by several fathoms of blaes, occurs in the Lyne Burn below Touch Bleachfield and in the stream north-west of Balbougie (1½ miles N.E. of Inverkeithing), and was correlated by Mr. Maufe with his Middle Kinniny Limestone.[2] Boring evidence has now shown that the distance by which it is separated from the Charlestown Main seam, previously unknown, is about 40 fms. It is a noticeably hard and compact bed, full of small encrinites, and generally 3 to 6 ft. thick. It was formerly quarried to a small extent in Lochornie Burn (4½ miles N. by E. of Dunfermline) and is exposed in The Dean (¼ mile N.N.W. of Roscobie quarries). One or two fathoms lower down a coal, 1 to 2 ft. thick, is also exposed, and has been proved in bores, while the intervening strata in The Dean are distinctly ashy in nature—features both of which occur in association with the Middle Kinniny Limestone. At The Dean and at Balbougie a thin poor limy ironstone with ribbed brachiopods is found about 8 ft. above the limestone in the otherwise nearly barren blaes, just beneath a band in which *Posidonomya corrugata* is the chief fossil.

Between the Mid Kinniny and Charlestown Main seams bores record at least two limy horizons. The higher of these is about 20 ft. below the coal, and is the Lower Kinniny Limestone, characterised by layers of *Lithostrotion irregulare*[3]; this coral also occurs in the only inland exposure of the seam at present known—in the Lochornie Burn at the foot of the upper reservoir. The lower horizon lies on the top of the sandstone which succeeds the blaes above the Charlestown Main; it generally takes the form of blaes containing ribbed brachiopods, and is seen at the old sandstone quarries of Mill Hill (300 yds. E. of Dunfermline Lower Station)[4] and of Duloch (500 yds. S. of Duloch Ho., 1 mile. N. of Inverkeithing). A 2-ft. encrinital limestone exposed in the Gask Glen a short way south of the bridge (400 yds. N.N.W. of Gask) appears to be the same horizon.

The Upper Kinniny Limestone, about 15 fms. above the Middle, is said to be characterised west of Charlestown by an abundance of *Bellerophon*. It rests on a limy sandstone containing traces both of plants and marine fossils, which along with the limestone is exposed at several places inland. In bores at Dunfermline this seam lies about 35 fms. below the Splint Coal.

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[1] Dunlop, R., 'Note on the Discovery of Fossil Chitons in Fife,' *Trans. Geol. Soc. Glasgow*, vol. xv, pt. ii, 1913–14, pp. 167–173 and plates.

[2] 'Summary of Progress' for 1905 (*Mem. Geol. Surv.*), 1906, p. 136.

[3] 'Geology of Central and Western Fife and Kinross' (*Mem. Geol. Surv.*), 1900, pp. 95, 96.

[4] *Spirifer* and *Productus* are recorded here by the Rev. Peter Chalmers, in 'History and Statistical Account of the Town and Parish of Dunfermline,' vol. i, 1844, p. 2.

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In Mr. Allan's ground, on the east side of the Fordel-Cowdenbeath syncline, the limestone quarried at Bucklyvie has been found to lie upon dark blaes containing a one-foot coal, but it is at present uncertain whether it represents the Charlestown Main or the Station seam. Two other seams have been detected in a stream west of Parkend, and are evidently some of the Kinniny Limestones.

(ii) *Correlations with Linlithgowshire and the Central Coalfield.*—The first detailed comparison of the minor Lower Limestones on either side of the Forth appears to be due to Mr. H. B. Maufe, who correlated[1] a limestone, seen below tuff ' in the railway cutting ¾ mile W. of Charlestown Station ' [close to Braeside Halt], with the Lower Carriden Limestone. He further compared[2] the Lower Kinniny Limestone with that of Wairdlaw in the Bathgate Hills (long known to lie above the Petershill Limestone), on account of the great abundance of *Lithostrotion*. Although his field maps record this coral close to the Braeside seam, and note the ashy beds above the Lower Kinniny Limestone, he seems to have considered that the evidence was not then sufficient to justify the further step of correlating these two beds with each other. If the truth of this correlation be assumed, however, and Mr. Maufe's measurements of the three Kinniny limestones be by this means joined up with those which he made of the strata between the Braeside and Charlestown seams on the other side of Ironmill Bay (as has been done in the second column of Fig. 11), it is found that the combined sequence is in such thorough agreement with the Carriden section (given in the first column, and derived from Mr. H. M. Cadell's[3] recent borings in the district) that there can no longer be any doubt of its correctness. The essential identity of the Dunfermline sequence (third column), derived from several overlapping bores, offers an equally convincing and entirely independent confirmation of this reading. The Braeside, Lower Kinniny, and Lower Carriden Limestones are then undoubtedly the same bed, and they are in all likelihood equivalent to the Wairdlaw seam.

The correspondence of the Upper, Mid and Lower Limestones of Kinniny with those of Carriden is well seen in the figure, and the Middle seams of the two districts further resemble each other in their hard, compact nature, their association with *Posidonomya corrugata*[4] and the presence of a coal among the underlying ashy sediments—evidently in the position of the Lillie's Shale Coal which throughout the Central Coalfield separates the two highest Hosie limestones from the others. An abundance of the lamellibranch referred to characterises the roof and pavement of the Top

[1] ' Summary of Progress ' for 1905 (*Mem. Geol. Surv.*), 1906, p. 136.
[2] ' Geology of Neighbourhood of Edinburgh ' (*Mem. Geol. Surv.*), 1910, p. 111.
[3] Cadell, H. M., *op. cit.*
[4] Not yet recorded from Kinniny, but found inland as mentioned above (p. 116).

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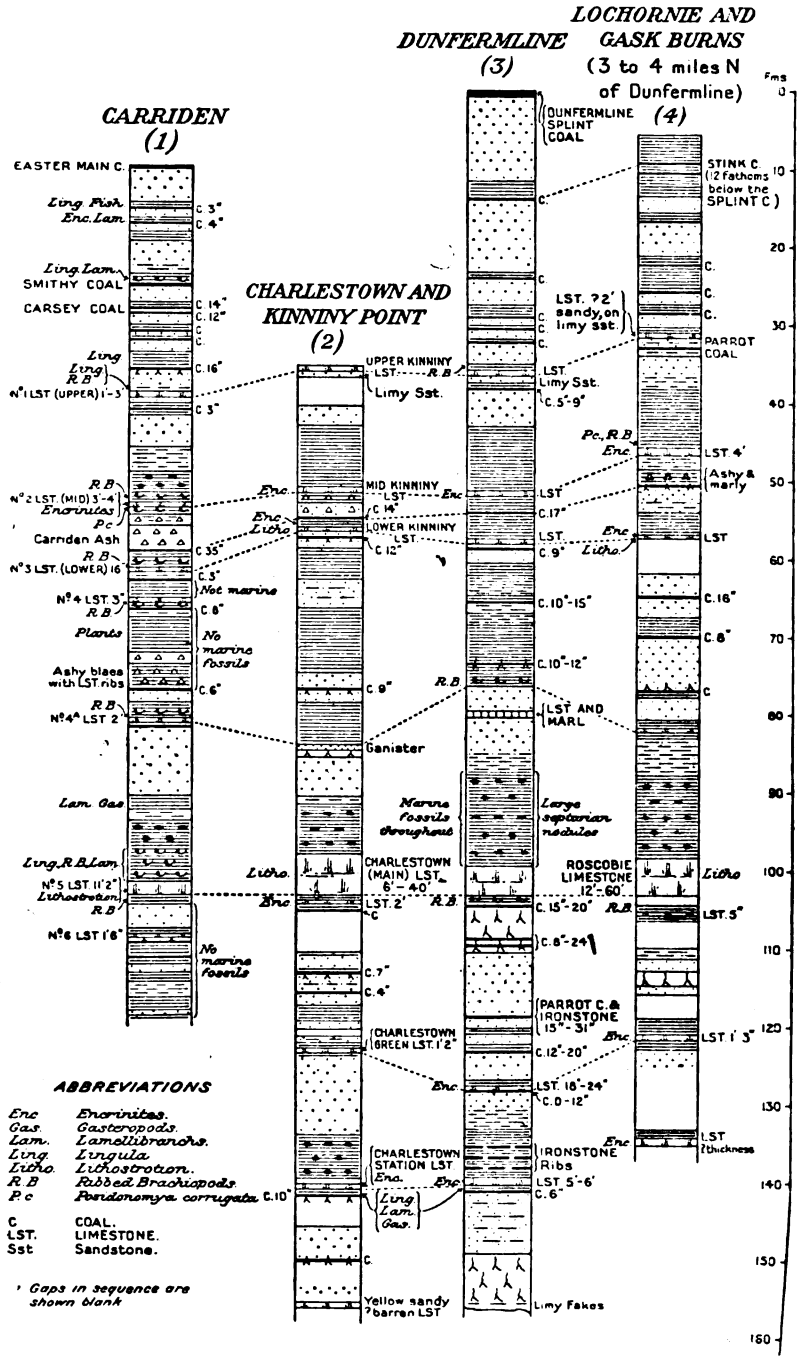
CARRIDEN (1)
CHARLESTOWN AND KINNINY POINT (2)
DUNFERMLINE (3)
LOCHORNIE AND GASK BURNS (3 to 4 miles N of Dunfermline) (4)
Fms
EASTER MAIN C.
Ling Fish.
Enc. Lam.
Ling. Lam.
SMITHY COAL
CARSEY COAL
Ling
Ling
R.B
N°1 LST (UPPER) 1'-3"
R.B
N°2 LST. (MID) 3'-4"
Enorinites
Pc
Carriden Ash
R.B
N°3 LST. (LOWER) 16"
N°4 LST. 3"
R.B
Plants
Ashy blaes with LST ribs
R.B
N°4A LST. 2"
Lam. Gas
Ling. R.B. Lam.
N°5 LST. 11'2"
Lichostreon
R.B
N°6 LST. 1'6"
No marine fossils
No marine fossils
C. 3"
C. 4"
C. 14"
C. 12"
C.
C.
C.
C. 16"
C. 3"
Enc.
Litho.
C. 35"
C. 3"
Not marine
C. 8"
C. 6"
UPPER KINNINY LST.
R.B
Limy Sst.
MID KINNINY LST.
Enc.
C. 14"
LOWER KINNINY LST.
C. 12"
C. 8"
R.B
Ganister
Marine fossils throughout
CHARLESTOWN (MAIN) LST. 6'-4.0"
Litho.
Enc.
LST. 2'
R.B
C.
C. 7"
C. 4"
CHARLESTOWN GREEN LST. 1'2"
Enc.
CHARLESTOWN STATION LST.
Enc.
Enc.
Ling.
Lam.
Gas.
C. 10"
C.
Yellow sandy ?barren LST
DUNFERMLINE SPLINT COAL
C.
C.
C.
C.
C.
LST. ?2' sandy, or limy sst.
LST. Limy Sst. C. 5'-9"
Pc. R.B.
Enc.
LST.
C. 17"
LST.
C. 9"
Litho.
C. 10"-15"
C. 10"-12"
R.B
LST AND MARL
Large septarian nodules
ROSCOBIE LIMESTONE 12'-60"
C. 15'-20"
R.B
C. 8"-24"
PARROT C. & IRONSTONE 15"-31"
Enc.
C. 12"-20"
LST. 18"-24"
C. 0-12"
IRONSTONE Ribs
LST. 5'-6"
C. 6"
Enc.
Limy Flakes
STINK C. (12 Fathoms below the SPLINT C.)
C.
C.
C.
PARROT COAL
LST. 4'
Ashy & marly
LST
C. 16"
C. 8"
C
LST. 5"
LST. 1' 3"
LST. ?thickness
Enc.
Litho.
Enc.
Litho.
Enc.
Enc.
Enc

Hosie Limestone, which is a calmy seam often containing *Bellerophon*, from Ayrshire eastwards to the two exposures of the normal Lower Limestone sequence nearest to Carriden (at Denny, 14 miles west, and the Skolie Burn, an equal distance to the south). In the Carriden and Fife districts this shell does not seem to be abundant at any horizon, nor are any of the limestones calmy; the Top Hosie Limestone accordingly cannot be exactly identified, but there can be no doubt that its position is either included in, or lies in the blaes a few feet above, the Middle Limestones of Carriden and Kinniny. The Upper seams of these last localities then correspond to the Slingstane Limestone (Johnstone Shell-bed) of the Central Coalfield, which in the Skolie Burn[1] is a two-foot encrinital bed, about 23 fms. above the Top Hosie. Still higher in the sequence as pointed out by Mr. Cadell[2] the *Lingula* band above the Bo'ness Smithy Coal matches one which overlies the Stink Coal of Fife, and the Easter Main Coal is the equivalent of the Dunfermline Splint.

In the lower part of the sequence, one of Mr. Cadell's bores[3] shows the marine horizons, Nos. 4 and 4*a*, between the Lower Carriden (No. 3) and the 11 ft. limestone No. 5. No. 4*a* overlies the first thick sandstone above No. 5; it contains *Spirifer* and *Productus* like the bands at Mill Hill quarry and Duloch already referred to (p. 116), to which it corresponds. The presence in Fife of a representative of No. 4 has not yet been determined, this part of the sequence being poorly exposed; it may be discovered during re-examination of the Charlestown section, not yet completed.

In the same bore No. 5 Limestone was for the first time met with in the Carriden district under conditions which leave no doubt that it is the equivalent of the Charlestown Main seam[4]: on no other assumption can the sequences in the first three columns be made to agree, and further facts indicated below all point in the same direction. Other reasons have been adduced elsewhere[5] for correlating the Charlestown Main Limestone with the Petershill Limestone of the Bathgate Hills, and the Carriden No. 5 with the Fankerton Limestone of Denny and Blackhall Limestone of the Central Coalfield. In particular the fauna discovered in the shales above No. 5 Limestone 'suggests comparison with the Neilson

[1] 'Economic Geology of the Central Coalfield, Area VI' (*Mem. Geol. Surv.*), 1923, pp. 35, 36.

[2] Cadell, H. M., 'A Volcano in the Bathgate Coalfield of West Lothian,' *Trans. Inst. Min. Eng.*, vol. lxv, pt. 5, 1923, p. 257.

[3] Published in condensed form in 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, pp. 86–88.

[4] In the 'West Fife Memoir,' and in papers on the local geology, the Charlestown Main Limestone is almost invariably termed the Hurlet Limestone. This name will in future be dropped; apart from the awkwardness and inadvisability of having no local name, free from implications, for this important seam, the correlation appears to be unsound.

[5] 'Summary of Progress' for 1905, p. 136; for 1919, pp. 35–38; for 1921, p. 88. 'Edinburgh Memoir' (*Mem. Geol. Surv.*), 1910, p. 116.

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Shell-bed overlying the Blackhall Limestone."[1] In the type district near Paisley the Blackhall Limestone is the first seam above the Hurlet, but eastward from Kilsyth and Auchenheath an extra seam (the Craigenhill or Bannock 'C' Limestone) intervenes. At first close to (and perhaps originating by a splitting of) the Hurlet seam, it gradually increases in distance from the latter until near Denny and Skolie Burn it lies about midway between the Hurlet and Blackhall positions.[2] Now the Charlestown Station Limestone has already been correlated on general grounds with the Hurlet Limestone of Cobbinshaw and the greater part of the Central Coalfield,[3] and this is borne out by the nature of the fossils found in the underlying blaes or 'alum shale.'[4] The thin limestone above it at Charlestown Green (p. 115) thus corresponds to the Craigenhill seam, so that the succeeding Charlestown Main Limestone becomes equivalent to the Blackhall, and its correlation with the No. 5 Carriden seam is arrived at once more by a different route.

It may be seen from the figure that the equivalent of the Hurlet Limestone lies about 40 fms. below the Charlestown Main. Since none of Mr. Cadell's bores went more than 15 fms. below No. 5 seam, or penetrated more than one marine limestone[5] below that bed it would seem that the true equivalent of the Hurlet Limestone lies below the No. 6 seam, and has not yet been unequivocally proved in the Carriden district.

Carboniferous Limestone Series: Limestone Coal Group.—In Mr. Haldane's area, near the western limits of the county, the ironstones of this group were actively wrought about the middle of the nineteenth century, and the coals from a much earlier period. Deeper parts of the field have since been opened up, and further development is expected at an early date. Much new information has been collected, mostly of a confidential nature, which will necessitate considerable alterations of the existing map, and in particular of the faults. The sequence of strata is shown in Fig. 12, which is generalised from numerous bores and sections.

In the coalfields around Cowdenbeath a large number of plans have been examined by Mr. Allan, and many bore journals collected from which the following general section has been compiled. It should be noted that while the sequence is regular from the Glassee Coal downwards, between this and the Lochgelly Blackband Ironstone, correlation becomes a matter of some difficulty owing

[1] 'Summary of Progress' for 1921, *loc. cit.*

[2] 'Economic Geology of the Central Coalfield, Area IX' (*Mem. Geol. Surv.*,) pp. 28, 45; *ibid.*, Area VI, pp. 34, 48, 61; 'Summary of Progress' for 1919, pp. 36, 38; *ibid.*, for 1920, p. 48.

[3] 'Edinburgh Memoir' (*Mem. Geol. Surv.*), 1910, pp. 116, 117.

[4] 'Edinburgh Memoir,' p. 373, localities 1a and 3. Prof. P. Macnair, 'The Hurlet Sequence in the East of Scotland . . .,' *Proc. Roy. Soc. Edin.*, vol. xxxvii, pt. 2, 1917, p. 204.

[5] This was got 2 ft. thick in Bore E^1, separated by about 10 fms. of partly faulted strata from the No. 5 Limestone above. 'Geology of the Blackness District,' *loc. cit.*, p. 202.

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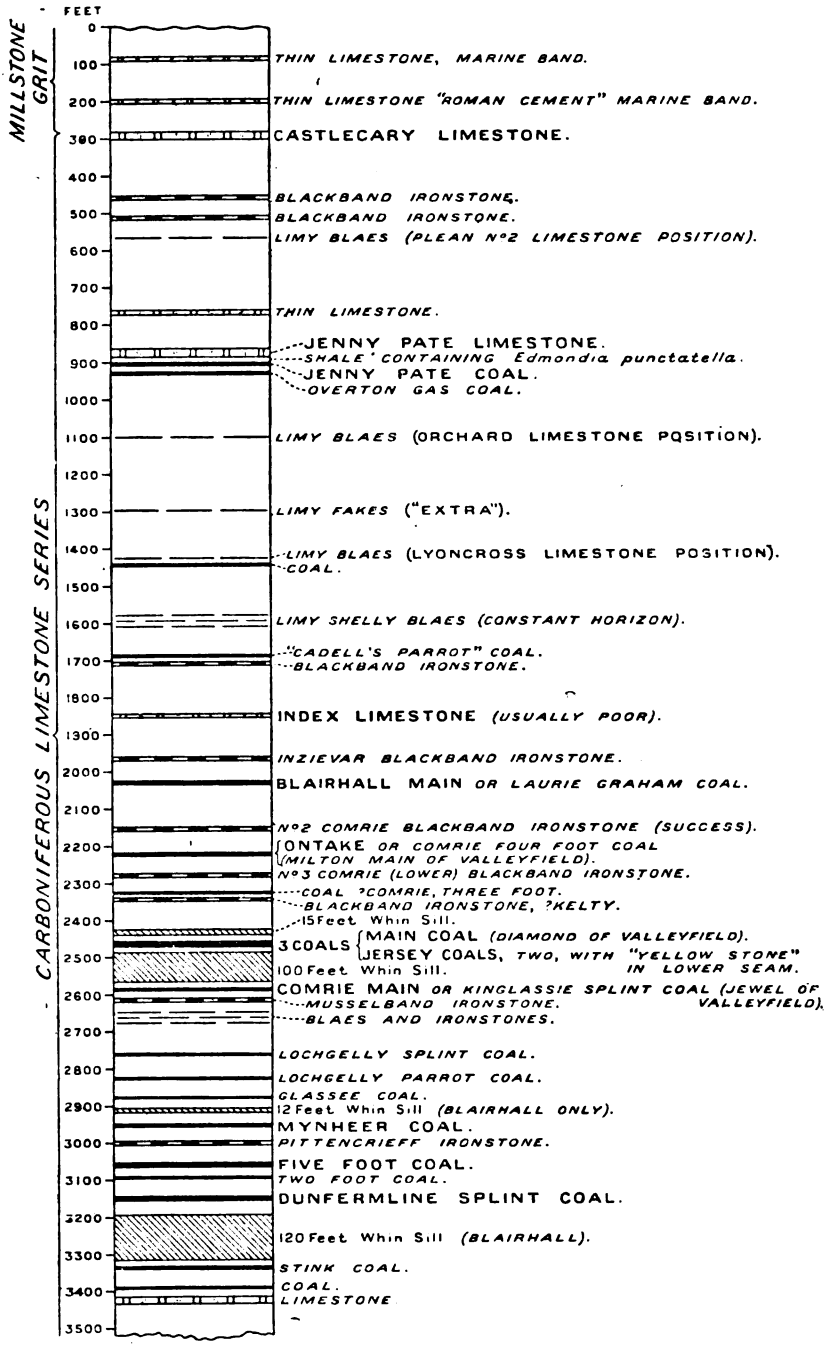

FIG. 12. *General Section of the Carboniferous Rocks in South-West Fife.*

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to the exceeding variability in thickness of the partings between the coals.

	Fms.	ft.	in.	Fms.	ft.	in.
Index Limestone	0	0	6	0	0	6
Strata	16	0	0	16	0	6
Blairhall Coal	0	2	7	16	3	1
Strata	2	0	0	18	3	1
Smithy Coal	0	2	2	18	5	3
Strata	11	0	0	29	5	3
Lochgelly Blackband Ironstone	0	2	0	30	1	3
Strata	3	0	0	33	1	3
Little Splint Coal	0	3	0	33	4	3
Strata (variable)	10	0	0	43	4	3
Rough Coal	0	3	0	44	1	3
Strata (variable)	20	0	0	64	1	3
Fourteen Feet Coal	1	0	0	65	1	3
Strata	3	0	0	68	1	3
Diamond or Jersey Coal	0	5	0	69	0	3
Strata	5	0	0	74	0	3
Swallowdrum Coal (in leaves)	0	4	6	74	4	9
Strata	17	0	0	91	4	9
Lochgelly Splint and Parrot Coals	2	0	0	93	4	9
Strata	20	0	0	113	4	9
Glassee or Blawlowan Coal	1	0	0	114	4	9
Strata	11	0	0	125	4	9
Mynheer Coal	0	3	6	126	2	3
Strata	5	0	0	131	2	3
Jewel or Upper Five Feet Coal	0	2	6	131	4	9
Strata	5	0	0	136	4	9
Five Feet Coal...	1	0	0	137	4	9
Strata	5	0	0	142	4	9
Wee and Two Feet Coal	0	2	3	143	1	0
Strata	5	0	0	148	1	0
Dunfermline Splint Coal	0	5	0	149	0	0

The distance from the Dunfermline Coal to the top of the Lower Limestone Group has not been proved except in the Raith district, where it approximates to 46 fms.

Carboniferous Limestone Series: Upper Limestone Group.—The crop of the Index Limestone at the base of this Group has for the first time been traced over the greater part of the district surveyed. Mr. Haldane has detected a new exposure among the muds of the foreshore at the S.W. end of Craigmore Rocks, Preston Island. The seam may also be seen at two abandoned quarries in the underlying fireclay at Lochhead and Lilliehill, north of Dunfermline. Though not exposed in Mr. Allan's ground, it is known to occur in the deeper parts of the field west of Cowdenbeath.

The correlations of some of the higher seams of this group are not yet fully determined, but it has long been supposed that the Jenny Pate Limestone and Coal represent the Calmy or Gair Limestone and Hirst or Shirva Coal of the Central Coalfield. This equivalence has been confirmed by Messrs. Haldane and Tait's

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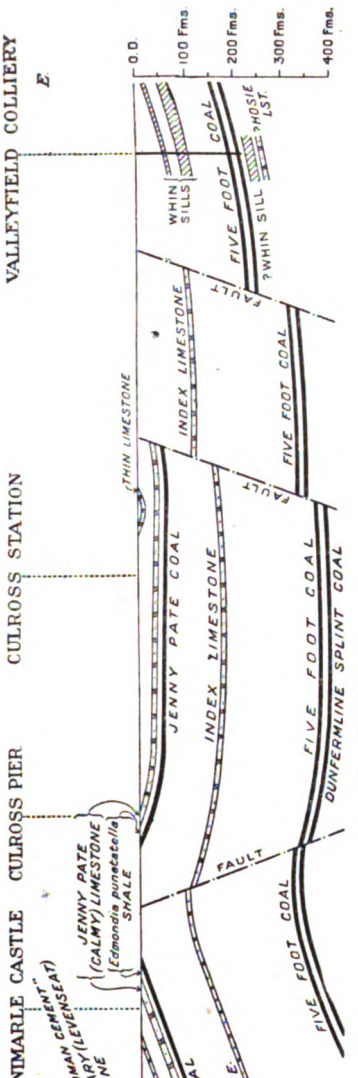

FIG. 13. *Diagrammatic Horizontal Section along the shore at Culross, Fife.*

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discovery this year of *Edmondia punctatella*—the first Fifeshire record—in a bituminous shale a short distance above the Jenny Pate Coal. This fossiliferous horizon was detected just west of Culross pier, on both sides of a subsidiary anticline near Dunimarle Castle (Fig. 13), and in the cores of a bore near Saline, four miles farther north.

The Castlecary Limestone at the top of the group outcrops on the east side of the old pier a quarter of a mile west of Dunimarle Castle, and is exposed at Caviehall a hundred yards inland. It is a pale crystalline encrinital seam, here 5 ft. thick, but only 2 ft. where seen 6 miles farther north, in the Black Devon river at Saline Shaw. An encrinital band has been noticed by Mr. Allan in the cutting at Cowdenbeath North Junction. It is in a thick blaes about 55 fms. above the Index Limestone, but cannot at present be definitely correlated with any known seam.

Millstone Grit.—Two thin impure limestones, yielding abundant fossils of Nebraskan type, have been discovered by Mr. Haldane on the shore 40 and 90 yds. respectively to the dip of the Castlecary seam (See Fig. 13). The lower of these is regarded as the probable equivalent of the Roman Cement limestone of Glenboig, or the No. 2 Marine Band of Torwood Glen, 9 miles to westward.[1] Five miles to the northward the same limestones reappear in a more complete section in the Rough Cleugh Glen, and yield a similar fauna. The section is as follows :—

		Ft.	in.
	Sandstone... ... ... seen	10	0
	Fireclay	2	0
	Limy fakes (hard shales), fossiliferous... ...	1	0
	Limestone, hard impure...	1	0
	Blaes	0	9
	Coal	0	8
	Fireclay, sandy	5	6
	Coal, hard...	0	6
	Fireclay	2	6
	Coal	2	0
	Fireclay, sandy	2	0
	Sandstone...	1	0
	Irony band	0	2
	Blaes, fossiliferous	7	6
'Roman Cement'	Cement limestone rib, shelly	0	6
	Limestone, impure	1	0
	Sandstone, flaggy ... ... seen	1	0

The sandstones of this series have been extensively quarried in the past, especially at Blair Castle, where a 5-ft. seam of fireclay resting on a clay ironstone with sphærosiderite grains has also been wrought, and a short distance farther westward an ironstone was obtained from old pits. The horizon of these beds is not exactly known, but it seems probable that the sandstone quarried at Longannet Point lies near the top of the series. Here, on the

[1] 'Economic Geology of the Central Coalfield, Area II' (*Mem. Geol. Surv.*), 1917, pp. 38–40; Area V, 1916, p. 20.

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west side of the main quarry, a foot of fossiliferous blaes is seen, resting on 9 in. of irony parrot or coaly blackband ironstone with *Lingula* and fish remains. This cannot be far from the position of the Crofthead Slatyband Ironstone, and so may be taken as the base of the Coal Measures; but exact correlation is not at present possible, since where this position has been examined in the nearest bores it has yielded neither blackband ironstone nor fossils, although *Lingula* bands have been met with at lower horizons among the top beds of the Millstone Grit.

Igneous Rocks.—In addition to the large volcanic vent west of Oakley Station, and its smaller subsidiary to the north[1], Mr. Haldane has found a third, in the railway cutting 600 yds. east of the main neck. At one place the large blocks in the agglomerate consist almost entirely of coal, with adherent bands of sandstone.

Intrusive sills of dolerite are numerous throughout the district. Their examination is not completed, but attention is being paid meanwhile to their behaviour near faults. When an intrusive sill meets a pre-existing or pene-contemporaneous fault it may either avail itself of the fracture to change both its level and its stratigraphical position, or it may pass straight across the fault at an approximately constant level into a different part of the sequence. The coincidence of whin escarpments with faults does not therefore prove that the faulting is later than the intrusion, as it is often assumed to do[2]. In fact, apart from visible surface evidence of fracture, the only *prima facie* case for a pre-fault age consists in a demonstration that the intrusion lies at the same stratigraphical horizon on either side of the fault. (i) In this district the intrusions appear to be not earlier than some of the W.N.W. faults, and Mr. Allan has obtained good evidence that this is the case with the 120 ft. sill which occupies a large area at the surface of the ground west of Cowdenbeath. At Dalbeath this sill lies 40 fms. above the Index Limestone; at Kirkford, on the other side of a fault which throws the strata 30 fms. downwards, the sill is 29 fms. higher in the sequence. The same phenomenon is reported between Lumphinnans No. 11 and Aitken Pits: the strata are thrown up 30 fms., and the position of the sill changes to the same extent in the opposite direction—from 14 fms. above to 15 fms. below the Index. (ii) In addition, Mr. Allan finds good reason to believe that some of this W.N.W. faulting is contemporaneous with the N.N.E. folding. (iii) On the other hand, the 'hair-pin' outcrop of dolerite shown on the one-inch map 3 m. N.N.W. of Dunfermline, where the ground is free from drift and where there can be no doubt about the mapping, can reasonably be interpreted only on the supposition that the intrusion is of not later date than the N.N.E. folding. The conclusion to be drawn from (i) (ii) and (iii) would appear to be

[1] 'Geology of Central and Western Fife' (*Mem. Geol. Surv.*), 1900, p. 137.

[2] *See* W. B. Wright, 'Summary of Progress' for 1908 (*Mem. Geol. Surv.*), 1909, pp. 66, 67.

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that the N.N.E. folding, the transverse W.N.W. faulting, and the dolerite sills were, in general, all more or less contemporaneous.

Glacial and post-Glacial.—The district is heavily covered with stiff blue boulder clay, largely in the form of drumlins whose axes, like the rare striæ, point in an east and west direction. A few sand and gravel mounds are seen near Bogside Station, and cover more extensive areas near Hill of Beath, and north of Moss Morran. This peat moss is known to reach to 30 ft. in thickness, and below it as much as 20 ft. of sand and gravel have been proved.

Raised beaches are well developed along the coast. In Mr. Haldane's ground the 100-ft. beach, with its cliff cut into boulder clay, is particularly well developed at Torry, and can be traced for three miles up the Bluther Burn. The 50-ft. beach is a marked feature along the whole of this part of the coast, its inner margin being proved by a steep bank or in places by a sea-worn sandstone cliff, and the 25-ft. beach is represented by a narrow strip on which stand the villages of Culross and Torryburn. Farther east some modification of the mapping of the 100-ft. beach margin may be required, and Mr. Allan finds reason to believe that the strips of alluvium on either side of the railway at Otterston ($2\frac{1}{2}$ m. E.N.E. of Inverkeithing) should perhaps be assigned to the beach deposits of this period.

C. H. DINHAM.

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4. WEST HIGHLAND DISTRICT

E. B. Bailey, M.C., B.A., District Geologist.
J. E. Richey, M.C., B.A., Senior Geologist.

The mapping of the plutonic complex of Ardnamurchan, and of the rocks which lie immediately to the east, has been completed by Mr. Bailey and Mr. Richey. The following notes, supplied by Mr. Richey, deal mainly with advances in regard to the plutonic complex, of which a map was given in last year's Summary.[1] Petrographical notes by Dr. Thomas have been incorporated.

Quartz-Gabbro Complex.—The strip of eucrite mapped on Beinn nan Ord has been found to extend northwards continuously to Sanna Bay, keeping closely parallel to the outer margin of the quartz-gabbro complex. It is now regarded as a distinct ring-dyke rather than a ' screen.' Mr. Bailey has recognised in the quartz-gabbro on its inner side, on the Beinn nan Ord ridge, a considerable development of fine-grained crush-rock, along shear-lines of earlier date than an associated complex of minor intrusions in the same locality. The eucrite immediately alongside shows neither crushing nor minor intrusions, and its later age thus seems demonstrated. The arcuate belt of quartz-gabbro, on the outer side of the eucrite, consists of an outer porphyritic fine-grained quartz-gabbro or dolerite, and an inner coarsely-crystallized quartz-gabbro. Sharp contacts between the two types have been observed south of Sanna Bay, and the belt is now regarded as consisting of two distinct ring-intrusions. Quartz-gabbro intrusions of different ages have been recognised in the complex belt between the Beinn nan Ord eucrite and the great ring of eucrite to the north-east. In some cases, these have been dated with reference to certain porphyritic basic cone-sheets. The latter were formerly considered to belong to a partially developed system. It is now evident that their failure to continue to the north and east is due to their truncation by later quartz-gabbro intrusions. For example, north-east of Beinn na Seilg a small area of older quartz-gabbro traversed by these cone-sheets terminates to the north against a later quartz-gabbro free of sheets. The older quartz-gabbro, together with the cone-sheets, is clearly contact altered (Slice Nos. 22680 and 22681). South-east of Achosnich, quartz-gabbro intrusions have been dated relatively to the great ring of eucrite. East of Aodann (1 mile S.E. of Achosnich), a porphyritic fine-grained quartz-gabbro is granulitized at its junction with the eucrite (22333). Some 20 yds. from the eucrite its alteration is only slight (22334). It is also granulitized in contact with a coarser-grained quartz-gabbro in this neighbourhood (22329). This later quartz-gabbro extends north-west of Aodann, where there is evidence of its being intruded into the eucrite (22317).

[1] Richey, J. E., ' Summary of Progress ' for 1922 (*Mem. Geol. Surv.*), 1923, Fig. 6, p. 99.

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Great Ring of Eucrite.—In the eastern sector, the distinctness of an inner from an outer eucrite is now more definitely established. The ridge of Meall nan Con is composed of agglomerate and early gabbros, which are for the most part highly granulitized. Junctions between these older rocks and the inner eucrite are vertical or steeply inclined. No contacts with the outer eucrite have been located, but the distinctness of the granulitized belt as a 'screen' separating the two eucrites is evident.

Ben Hiant Intrusion.—Ben Hiant is largely composed of a great intrusion of quartz-olivine-dolerite. The earlier sediments, lavas and agglomerates[1] outcrop on its lower slopes, except on a steep west face where the dolerite extends down to sea-level. This dyke-like portion of the intrusion, half a mile in width along the shore, may be its feeder, and at a higher level the intrusion spreads out to override the surrounding country rocks with an inclined or apparently flat base.

In the low ground, north of the summit, sheet-like extensions of the main mass have been mapped. One of these has been traced for over half a mile northwards. They have the same direction and inclination as cone-sheets in their neighbourhood, but differ in composition, for the quartz-dolerite cone-sheets are free of olivine. The Ben Hiant intrusion lies just outside the main cone-sheet belt, but an isolated sheet, a quartz-dolerite of Talaidh Type, cuts an outlying portion on Stallachan Dubh, south of the main mass.

E. B. BAILEY.

[1] Richey, J. E., 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, pp. 90–91.

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5. NORTH HIGHLAND DISTRICT

M. MACGREGOR, M.A., B.Sc., District Geologist.
H. H. READ, M.Sc., A.R.C.Sc.
G. ROSS, B.Sc. } Geologists.
J. PHEMISTER, M.A., B.Sc.

In Sutherlandshire field-work was carried on in one-inch Sheet 103 (Golspie and Brora Sheet) by Messrs. Read, Ross and Phemister. The revision of the crystalline schist and Old Red Sandstone areas of the Sheet,[1] undertaken in 1922 with the object of preparing a colour-printed edition to show 'drift' geology in addition to 'solid', has now been completed. The Glacial deposits and the peat mosses were mapped in detail while a re-examination of the igneous rocks was carried out and material collected for subsequent petrographical examination. The information obtained has been incorporated in the new edition of the Sheet now being engraved. In continuation of the primary six-inch survey of Sutherland a small area in Sheet 108 (Altnaharra) was surveyed by Mr. Phemister.

The examination of the rock-slides from Sheet 102 (Lairg) has been carried out by Messrs. Read and Phemister and the memoir on the geology of this Sheet is nearly completed.

In Sheet 103 Mr. Read has continued the investigation of the granulites and granite-granulite complexes of the Lairg and Rogart districts mentioned in last year's 'Summary of Progress' (pp. 109–111). The area revised lies mainly north of the River Brora in the ground drained by the Black Water and its tributaries.

Moine granulites, comparatively free from granitic material, occupy the district east of a line joining Sciberscross and Pollie. They are uniform in character, consisting of the normal quartz-biotite-granulite, and have a general easterly dip. The only departures from this type are provided by two narrow belts of mica-schist outcropping in the Achaness Burn which joins the Black Water 2½ miles above Balnacoil Lodge. Throughout this quarter the siliceous granulites are traversed by many thin veins of pink granite, aplite and pegmatite, emanating from the granite masses lying to the west. Intrusions of earlier date than the regional metamorphism are limited to a few sills of hornblende-schist, seen, for example, in the Black Water at Balnacoil Lodge.

West of this region of granulite the granite-granulite complexes are well developed. The completion of the mapping of the Lairg-Rogart hornblende-granite shows that this mass is flanked on all natural sides by an intimate lit-par-lit complex of biotite-granite and siliceous granulite. At Dalreavoch Lodge, this marginal zone turns eastwards and runs up the river Brora into Sheet 102, being well seen, for instance, on the great rock-faces of Grumby

[1] The Jurassic rocks had already been revised by Dr. Lee.

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Rock and Cnoc na Sguaibe. Outside this marginal zone there is one composed mainly of siliceous granulites, but intruded by innumerable veins of granitic material ; this zone passes outwards into the siliceous granulite with fewer granitic veins already described.

A narrow belt of granulite with much granite veining separates the marginal zone of the Lairg-Rogart granite mass from a second complex occupying the N.W. corner of Sheet 103 and the N.E. corner of Sheet 102, on the north side of the Brora about the Coirefrois Burn. The northern boundaries of this complex have not yet been found, but it seems likely that it stretches into the Clibreck and Ben Armine country. This new complex is similar to that at the margin of the Lairg-Rogart mass, being made up of an intimate lit-par-lit mixture of biotite-granite and siliceous granulites. The fluxion of the granitic parts of this complex and the disposition of the Moine inclusions show agreement with the regional strike of the surrounding granulites, and with the margin of the complex against them.

Whilst the non-granitic part of this complex is usually formed by siliceous granulite, there are in a few localities narrow belts of pelitic rock with which the granite forms a complex of remarkable type. The pelitic schists are injected with granitic material which takes the form of large felspar or quartz-felspar augen between which are curved felts of biotite. All stages can be seen from the sporadic spotting of the schist with felspar crystals to noded veins or even to thick veins formed of felspar augen separated by thin films of biotite. The rocks produced recall in every detail the albite-porphyroblast-schists and the injection-gneisses described by Prof. V. M. Goldschmidt[1] from the Stavanger district of Norway. Such augen-injected rocks can be well seen on the east shore of Lochan Dubh 2 m. N. of Dalreavoch Lodge, on the Black Water 1 m. above Creagandamph, on the tributary of the Black Water 1¼ m. N. of Pollie, and between Lochan Dubh and Loch na Glaic.

Scyelite and other ultrabasic rocks, and their hybrids with granite, are not here developed so well as in the ground farther south described in last year's ' Summary of Progress ' (p. 110). Ten small masses have been encountered, the best being seen near the River Brora 4¼ m. above Dalreavoch Lodge.

In the Brora above Braegrudie, there are several thick sills of hornblende-schist belonging to the period of igneous activity that preceded the regional metamorphism.

The area revised by Mr. Ross lies east of a line running from Loch Coir' an Eoin to Kilbrare Hill and thence south-east along the northern slopes of Cagar Feosaig as far as the Jurassic boundary fault. The eastern margin follows this fault line as far as Lothbeg, then swings up Glen Loth and Glen Sletdale, and passes northwards across Beinn Dhorain. The northern margin is an irregular

[1] Videns. Skrift. I, Mat.-naturv. Klasse, 1920, No. 10.

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line passing through Cnoc Meadhonach and north of Cnoc nan Crubag to a point half a mile N.W. of Ben Uarie.

The rocks of this area are principally siliceous schists and granulites with many veins and irregular intrusions of a reddish acid granite. On the eastern margin of the area, near Lothbeg, the schists are invaded by the edge of a large granite batholith.

An outlier of Lower Old Red Sandstone rests unconformably upon the schist foundation and partly upon the western edge of the granite, in a broad belt with its eastern margin of basal conglomerate extending in a great dissected escarpment from Carrol Rock across Loch Brora north-eastwards to the Craggan. Its western margin, partly of basal conglomerate and partly of sandstone, extends, also in an escarpment, from Cagar Feosaig across the outlet of Loch Brora to Killin Rock, north-east to Cnoc na h-Iolaire, and thence northwards to Ben Uarie.

The schists and granulites to the west of this outlier form an eroded platform of low relief with an almost continuous covering of drift. Good rock sections are, however, exposed in Allt a' Mhuilinn and Allt Smeorail and these show the prevailing dip to be nearly E.S.E. at high angles. The strip of schists exposed on the eastern edge of the Old Red Sandstone is similar in character, but the schists show less granite veining and the dip, while in general easterly, varies more in direction and amount.

The topography of the Lower Old Red Sandstone is in striking contrast to that of the schists, the basal conglomerates of the eastern margin weathering into a line of conical peaks, of which Beinn Smeorail (1,592 ft.) is the most conspicuous. Towards the centre of the outlier the flaggy horizontally-bedded sandstones forming the mass of Col Bheinn give rise to a succession of well-marked ledges from base to summit, while Ben Uarie (2,046 ft.) and Beinn Dhorain (2,060 ft.) are sculptured out of an escarpment of flaggy sandstone dipping south-westwards at from 15° to 20° along the north-eastern margin of the outlier.

The whole of this area of high relief is comparatively free from drift, but the eastern strip of schists is thickly covered with stony drift of local derivation, principally conglomerate and flaggy red sandstone.

The area of granite south and west of Helmsdale was revised by Mr. Phemister, who reports an uncommon type of variation in the granite. The latter is very coarse-grained and contains porphyritic felspars one inch long all along the western and southern margins. This coarse type contains a little biotite usually very decomposed. From the margin inwards the grain-size becomes progressively smaller, and the felspar phenocrysts both smaller and rarer till the rock resembles a hypabyssal rather than a plutonic type. Biotite still occurs in the rock, but there are wide areas in which no ferromagnesian mineral is apparent and in hand-specimens the rock might then pass for an aplite.

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A noteworthy feature of the passage from the coarse porphyritic type to the fine non-porphyritic type is the occurrence of a passage-rock in which quartz becomes porphyritic, though not euhedral, and the rock then bears a strong resemblance to the Grudie Granite described by Mr. Read.[1]

At the contact of granite and schist in the burn one and a-quarter miles E.N.E. of A'Chrasg (Glen Loth) it is clearly seen that the sole effect on the schists has been to bake them slightly and to cause violent shattering for some distance from the margin.

The primary survey of one-inch Sheet 108 was continued by Mr. Phemister in the area immediately south-west of Altnaharra and west of the Lairg-Tongue road. He finds that the rocks consist of felspathic granulites containing more or less biotite and occasionally muscovite. Thin bands of biotite-schist are common in places. The dip of the rocks is very variable owing to the existence of many isoclinal folds, but in general the dip is easterly at 15° to 40° and the axis of the isoclinal folding is always approximately S.S.E., which agrees with the previously observed directions of dip and folding round Loch Harrald, An Glas Loch, Creag Dubh Mhor and Creag Dubh Beag. On the hillside opposite the shepherd's house at Vagastie the dip swings round to the S.S.E. and a large granite sill indicates the proximity to the granite-schist complex on the east.

An isolated exposure of very massive hornblende-epidote-schist was observed three quarters of a mile S.S.W. of Altnaharra Hotel. Its relations to the schists are rather obscure, but it seems to cut the foliation at a low angle and is therefore definitely intrusive.

M. MACGREGOR.

[1] 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, p. 102.

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III.—PETROGRAPHICAL WORK

1. England and Wales

In England petrographical material has been collected by the various field-staffs, during the past year, from the borders of the Lake District, the Cheviots, and the Welsh Borderland, and will be dealt with by the Petrographer in due course. There have been many inquiries from private individuals and Government Departments. Amongst the investigations may be mentioned one carried out at the instigation of the Mines Department on the nature of the materials used for dusting the roads of mines.

2. Scotland

Dr. Thomas and Mr. Bailey have been concerned chiefly in preparing the petrography of the Island of Mull (Sheet 44) for publication. They have also been occupied with the descriptive petrology of the Ross of Mull, Iona, Tiree, Coll and the mainland of Ardnamurchan for the purposes of forthcoming memoirs. Mr. Richey has co-operated with Dr. Thomas on the petrography of Ardnamurchan and the results are mainly incorporated in the descriptions of field-work given by Mr. Richey.

Mr. Read has continued his petrographical work in the Banff, Turriff and Huntly Districts and Mr. Phemister has had under investigation an interesting series of alkaline intrusive rocks from Sutherlandshire.

H. H. Thomas.

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IV.—CHEMICAL WORK

In 1923, the analyses of twenty-three samples were completed, and, at the end of the year, twenty-four analyses were in progress.

Two Iron ore analyses are to be published in a Memoir on Sedimentary Iron Ores. The method of analyses, given in the 'Summary of Progress' for 1922, has been somewhat modified to facilitate its application to certain argillaceous Welsh ores; this will be fully described in the Memoir.

Of the remainder, those of outstanding interest are appended.

Final Contamination Product of Arnage Norite.—Quarry, roadside 320 yds. S.S.E. of Ardlethen, Ellon. 1-in. map, 87; 6-in. Aberdeen, 38 S.W. Slice No. 21169. Lab. No. 700. For comparison with uncontaminated granites.

Xenolith in Contaminated Norite.—Gallow Hill Brae, 400 yds. W. of Gallowhill Farm, 3 m. N.N.W. of Ellon Station. 1-in. 87; 6-in. Aberdeen, 38 N.W. Slice No. 21170. Lab. No. 701. For composition of Cordierite (Main constituent).

Plutonic Intrusion in Nickeliferous Pyrrhotite.—316 yds. E. 35½° S. of Talnotry Cottage, 5 m. E. 41 N. of Newton Stewart, Kirkcudbright. Slice No. 21171. Lab. No. 702.

As Lab. No. 702, but taken 335 yds. E.16° S. of Talnotry Cottage. Slice No. 21172. Lab. No. 703.

	Lab. No. 700.	Lab. No. 701.	Lab. No. 702.	Lab. No. 703.
SiO_2	69·84	45·85	51·96	65·19
TiO_2	0·60	1·15	1·01	0·59
Al_2O_3	13·16	20·50	11·93	16·31
Fe_2O_3	1·45	11·91	0·65	0·61
Cr_2O_3	—	—	0·06	nt. fd.
FeO	2·37	11·32	8·43	3·44
MnO	0·15	0·26	0·41	0·17
(CoNi)O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	0·11	nt. fd.	nt. fd.	nt. fd.
CaO	2·13	1·27	7·28	3·41
MgO	1·06	4·18	11·06	1·50
K_2O	5·68	0·72	3·44	2·95
Na_2O	3·07	1·27	2·75	4·72
Li_2O	nt. fd.	nt. fd.	trace.	nt. fd.
H_2O at 105° C.	0·09	0·07	0·12	0·15
H_2O above 105° C. ...	0·06	1·48	1·34	1·16
P_2O_5	0·14	0·04	0·12	0·22
FeS_2	0·01	0·07	nt. fd.	nt. fd.
CO_2...	0·09	nt. fd.	0·09	0·03
TOTALS	100·01	100·09	100·65	100·45

Analysed by E. G. RADLEY.

The following six analyses form a series representing definite types of lavas of Calciferous Sandstone age.

Trachyandesite.—Scarp, W. side of Ballagioch Hill, 3 m. W.S.W. of Eaglesham. 1-in. 22; 6-in. Ayr, 18 N.E. Slice No. 21174. Lab. No. 707.

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Porphyritic altered rhyolite.—566 yds. W.N.W. of Loganswell, 4 m. W. of Eaglesham. 1-in. 22; 6-in. Ayr, 16 S.E. Slice No. 21177. Lab. No. 708.

Hornblende-olivine-trachyandesite allied to kulaite.—Quarry by roadside, 1000 yds. E.S.E. of Lugton. 1-in. 22; 6-in. Ayr, 9 S.W. Slice No. 21180. Lab. No. 709.

Bostonitic trachyte.—Scarp on slope, 725 yds. E. 4° S. of Townhead of Grange, Lugton. 1-in. 22; 6-in. Ayr, 9 S.W. Slice No. 21183. Lab. No. 710.

Orthophyric augite-trachyandesite with abundant pseudomorphs after olivine; allied to mugearite.—Quarry, N. side of Black Law, 3½ m. E. 9° N. of Dunlop. 1-in. 22; 6-in. Ayr, 9 S.E. Slice No. 21185. Lab. No. 711.

Felsitic rock of trachytic suite.—S.E. side of large knoll, 660 yds. W. 8° N. of Swinlees, Dalry. 1-in. 22; 6-in. Ayr, 7 S.E. Slice No. 21187. Lab. No. 712.

Lab. No. ...	707.	708.	709.	710.	711.	712.
SiO_2	58·30	73·79	54·60	59·15	56·93	72·87
TiO_2	1·40	0·26	0·92	0·31	1·24	0·26
Al_2O_3	18·13	14·05	19·68	19·30	18·31	13·33
Fe_2O_3	3·59	1·26	5·13	3·65	5·25	1·86
FeO	0·90	0·22	2·05	1·31	1·92	1·23
MnO	0·23	0·11	0·25	0·12	0·20	trace.
(CoNi)O ...	nt. fd.	nt. fd.	nt. fd.	nt. fd.	nt. fd.	trace.
BaO	0·10	nt. fd.	0·12	0·07	0·12	0·11
CaO	3·11	0·32	3·31	1·75	3·93	0·21
MgO	2·36	0·20	2·50	0·92	1·74	1·25
K_2O	3·72	4·57	3·58	5·15	3·83	4·65
Na_2O	5·83	3·85	4·20	6·35	5·37	0·15
Li_2O	nt. fd.	trace.	nt. fd.	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	0·90	0·28	1·70	0·48	0·31	0·82
H_2O above 105° C.	1·23	1·31	2·31	1·65	0·96	3·07
P_2O_5	0·40	0·06	0·11	0·34	0·42	0·06
FeS_2	nt. fd.	nt. fd.	0·06	0·04	0·05	0·13
CO_2	0·06	0·07	0·03	nt. fd.	0·04	0·05
Cl	—	—	—	—	—	trace.
TOTALS ...	100·26	100·35	100·57	100·59	100·62	100·05

Analysed by E. G. RADLEY. Analysed by R. SUTCLIFFE.

Upper Cretaceous Sandstone. Roadside cliffs, W. shores of Loch Aline, ½ m. N.E. of Pier, Morven, Argyll. Sandstone suitable for glassmaking. 1-in. 44; 6-in. Argyll, 70 N.E. Slice No. 21276. Lab. No. 719.

Okaite. Husereau's Farm, Oka, Quebec, Canada. Slice No. 2491. Lab. No. 740.

	Lab. No. 719.	Lab. No. 740.
SiO_2...	99·69	30·13
TiO_2	—	2·38
Al_2O_3	0·11	11·02
Fe_2O_3	0·02	7·34
FeO...	—	4·17
MnO	—	0·52
(CoNi)O	—	0·05
CaO...	0·02	22·48
BaO	—	0·89

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	Lab. No. 719.	Lab. No. 740.
MgO	0·01	12·01
K_2O	—	2·07
Na_2O	trace.	1·43
Li_2O	—	nt. fd.
H_2O at 105° C.	—	0·13
H_2O above 105° C.	—	0·82
P_2O_5	—	2·88
FeS_2	—	0·13
Fe_7S_8	—	0·32
SO_3	—	0·11
CO_2	—	1·17
Cl	—	trace.
Loss on ignition	0·12	—
TOTAL	99·97	100·05

Analysed by
R. SUTCLIFFE. F. R. ENNOS.

R. SUTCLIFFE.

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V.—PALÆONTOLOGICAL WORK

In London

F. L. KITCHIN, Sc.D., PH.D., Palæontologist (District Geologist).
J. PRINGLE, Assistant-Palæontologist (Senior Geologist).
C. P. CHATWIN, Assistant-Palæontologist (Geologist).

In Edinburgh

G. W. LEE, D.Sc., Senior Geologist.

I. ENGLAND AND WALES

The memoir on 'The Concealed Mesozoic Rocks in Kent,' which was published in October, contains much palæontological information relating in particular to the Jurassic rocks and their zonal representation beneath the Cretaceous cover in that county.

Parts I.–IV. of Dr. R. Kidston's important memoir on the 'Fossil Plants of the Carboniferous Rocks of Great Britain' (*Mem. Geol. Surv., Palæontology*, vol. ii.) have been issued during the year.

During the summer the cutting for the new road through Swanscombe Hill, Kent, was examined and collections of fossils were made from the Woolwich Beds and from sands in the Oldhaven series. Mr. C. P. Chatwin and Mr. A. Templeman also visited Burham, Kent, where fine sections in a series of quarries and cuttings expose an almost continuous succession from the Gault up to the Middle Chalk. A collection of fossils was made, including numerous ammonites from the lower beds of the Chalk.

In the course of collecting from the Upper Chalk of Kent (Sheet 271), Mr. Chatwin found that a hard nodular band, similar in some respects to the Chalk Rock, marks the top of the Planus Zone. This bed corresponds therefore with the 'Top Rock' of the Chiltern area. The presence in it of *Solariella gemmata* (J. de C. Sow.) is an interesting record.

During the year Mr. Pringle continued his visits to the boring at Adisham, near Canterbury, by kind permission of Mr. E. O. Forster Brown. This boring has now been completed and a full record has been made of the formations penetrated. Incidental references to some of the beds passed through at Adisham were inserted in the memoir on 'The Concealed Mesozoic Rocks in Kent' while that work was passing through the press. It has been shown that at this locality the Wealden series rests upon the middle part of the Oxford Clay. In the Cornbrash were found specimens of the somewhat rare brachiopod *Rhynchonella major* Desl. (*non* J. de C. Sow.). The Lias is represented by only about 13 ft. of clays and limestones, comprising a portion of the Capricorn Beds, some uppermost part of the Middle Lias, and the Tenuicostatum Zone in thin development. After passing through the Coal Measures the boring ended in the Carboniferous Lime-

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stone. A full account of this section will be prepared in due course.

During the work of revision carried out in the Jurassic rocks in Wiltshire (Sheet 266), fossils were found which showed that the Vertebrale Zone of the Corallian series is present in sandy facies, underlain by somewhat sandy grey clay, also of Corallian age but formerly mapped as Oxford Clay. The fossils indicate that this clay may be correlated with a part at least of the Scarburgense Zone of Mr. Buckman's classification.

In collaboration with Dr. G. W. Lee, Dr. Kitchin and Mr. Pringle examined a series of Kimmeridge fossils from the Brora—Helmsdale and Eathie districts in Scotland; these provided material for the determination of the zones there represented. The results will be dealt with by Dr. Lee.

A collection of plants from the Coal Measures of South Wales, kindly presented by Mr. David Davies, of Gilfach Goch, forms an important supplement to the specimens obtained by the Geological Survey during the revision of the South Wales Coalfield.

Arrangements have been made to add to the Museum collection a large number of types of Jurassic ammonites. A series of large specimens illustrating the zones of the Portland Series has already been placed on exhibition; but the work on the remainder has been delayed owing to the presence of scaffolding erected in the Museum for the repair of the building.

The following specimens in the Museum have been figured, described or mentioned in publications—

In the Quarterly Journal of the Geological Society, Volume LXXVII.

The Charophyta of the Lower Headon Beds of Hordle Cliffs (South Hampshire).

By the late Mr. Clement Reid, F.R.S., F.L.S., F.G.S., and Mr. James Groves, F.L.S.

Chara wrighti *Salt.*, pl. iv, fig. 1, p. 183 (6 specimens).
" " *var.* minor *Reid & Groves*, pl. iv, fig. 2, p. 184 (2 specimens).
" " *var.* rhytidocarpa *Reid & Groves*, pl. iv, fig. 3, p. 184.
" " ? *Salt.*, pl. iv, fig. 11, p. 184.
" cælata *Reid & Groves*, pl. iv, figs. 4-6 (3 views), p. 184.
" " *var.* bicincta *Reid & Groves*, pl. iv, figs. 7, 8 (2 views), p. 184.
" " *var.* baccata *Reid & Groves*, pl. iv, figs. 9, 10 (2 views), p. 184.
" " ? *Reid & Groves*, pl. vi, fig. 9, p. 185.
" vasiformis *Reid & Groves*, pl. iv, figs. 12–15, p. 185 (10 specimens).
" tornata *Reid & Groves*, pl. v, figs. 1, 2, p. 187 (6 specimens).
" subcylindrica *Reid & Groves*, pl. v, fig. 4, p. 187.
" strobilocarpa *Reid & Groves*, pl. v, figs. 7, 8 (2 views), p. 187.
" " *var.* ellipsoidea *Reid & Groves*, pl. v, fig. 10, p. 188 (2 specimens).

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Chara polita *Reid & Groves*, pl. v, figs. 9, 12, p. 187 (7 specimens).
,, helicteres *Brongn.*, pl. v, fig. 11, p. 186.
,, sp. ?, pl. vi, fig. 7.
,, sp. Type A., pl. vi, figs. 10-12, p. 189 (8 specimens).
,, sp. ,, B., pl. vi, fig. 13, p. 190.
,, sp. ,, C., pl. vi, fig. 14, p. 190 (2 specimens).
,, sp. ,, D., pl. vi, figs. 15, 16, p. 190 (3 specimens).
,, sp. ,, E., pl. vi, figs. 17, 18, p. 190 (2 specimens).
,, sp. Stem-nodes ?, pl. vi, figs. 19-21, p. 190 (5 specimens).
Tolypella headonensis *Reid & Groves*, pl. vi, fig. 3, p. 188 (8 specimens).
,, parvula *Reid & Groves*, pl. vi, fig. 4, p. 188 (9 specimens).

In the Quarterly Journal of the Geological Society, Volume LXXIX.

The Upper Ordovician Rocks of the South-Western Berwyn Hills.

By Mr. W. B. R. King, O.B.E., M.A., F.G.S.

Calymene quadrata *King*, pl. xxvi, fig. 1, p. 504 (2 specimens).

In Proceedings of the Geologists' Association, Volume XXXIV.

Excursion to Folkestone, with Notes on the Zones of the Gault.

By Dr. L. F. Spath, F.G.S.

" Hoplites " sp. nov. (= tuberculatus " *var.*" of Price), p. 75.

The Tertiary section at Shorne Wood, Cobham, Kent.

By Mr. R. H. Chandler.

Cyrena spp., p. 141 (2 specimens).

In Memoirs of the Geological Survey of Great Britain. —Palæontology.—Volume II. (Parts 1–4).

Fossil Plants of the Carboniferous Rocks of Great Britain.

By Dr. R. Kidston, LL.D., F.R.S., F.G.S.

Sphenopteris obtusiloba *Brongniart*, pl. iv, fig. 5, p. 27.
,, polyphylla *Lindley & Hutton*, pl. xi, figs. 1, 1a–c, p. 55.
,, flexuosissima (*Stur*), pl. xxii, figs. 4, 4a–c, p. 107.
,, selbyensis *Kidst.*, pl. xxix, figs. 1, 1a, p. 130.
Rhacopteris dubia (*Lindley & Hutton*), pl. li, figs. 1, 1a, p. 210.
,, subcuneata *Kidst.*, pl. liv, figs. 3, 4, p. 217 (2 specimens).
Diplotmema patentissimum (*Ettingshausen*), pl. liv, fig. 5, p. 253.
Zeilleria moravica (*Ettingshausen*), pl. lxii, figs. 3, 4, 5 (2 specimens).
Coryrepteris sternbergi (*Ettingshausen*), pl. lxxiv, figs. 5, 5a–d, p. 301.
Urnatopteris herbacea (*Boulay*), pl. lxxxiv, figs. 4, 5, 5a, p. 361.
Crossotheca sagittata (*Lesquereux*), pl. lxxxvii, fig. 3, p. 350.
Rhodea feistmanteli *Kidst.*, p. 235.
,, sp., p. 238 (5 specimens).
Alloiopteris quercifolia (*Goppert*), p. 306 (2 specimens).

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In Type Ammonites, Volume IV., 1922–1923.

By Mr. S. S. Buckman, F.G.S.

Dolikephalites dolius *S. Buckm.*, pl. ccclxxii, figs. 1, 2.
Pectinatites aulacophorus *S. Buckm.*, pl. ccclxxxi, figs. 1, 2, 3.
Paravirgatites desideratus *S. Buckm.*, pl. ccclxxxii, figs. 1, 2.
Wheatleyites opulentus *S. Buckm.*, pl. ccclxxxiiiB, figs. 1, 2.
Gulielmites conlaxatum *S. Buckm.*, pl. cdxviii, figs. 1, 2a, 2b.

In Type Ammonites, Volume V., 1923–1924.

By Mr. S. S. Buckman, F.G.S.

Prorsisphinctes meseres *S. Buckm.*, pl. cdxlvi, figs. 1, 2.
Micromphalites micromphalus (*Phill.*), pl. cdliii, figs. 1, 1a, 2.
Cawtoniceras cawtonense (*Blake & Hudleston*), pl. cdliv, figs. 1, 1a, 2.

In Transactions of the Leeds Geological Association, Part XIX.

Gastrioceras cancellatum (*sp. nov.*) *at Meanwood, Leeds.*

By Mr. W. S. Bisat, F.G.S.

Gastrioceras cancellatum *Bisat*, pl. viii, p. 47.

2. Scotland

The fossils collected during the year were obtained from the Carboniferous Rocks of Scotland and Northumberland. As the collecting was done in connexion with the mapping of various sheets under revision, most of the results of the examination of the material are not of sufficient general interest to be quoted here, and will be referred to elsewhere.

In the 'Summary of Progress' for 1922, p. 123, mention is made of an attempt to trace evolutionary steps in *Productus giganteus* (Mart.) which could serve in the identification of certain Scottish limestones. Further material obtained since from adjoining districts appears to support the original observation to the effect that the fully grooved or furrowed form is succeeded by one in which the furrows become evanescent in the umbonal region.

Of the Carboniferous Limestone localities searched by Mr. D. Tait for the Newcastle unit, one, on the eastern side of Berwick, is of interest on account of its having yielded a number of small *Producti* not referable to any known British species. Their horizon lies between the second and third limestones below the 'Eelwell' Limestone, and should it prove constant, it might be of use for correlation purposes.

The stratigraphical significance of certain Carboniferous fossils from Scotland is more fully dealt with on other pages, but mention may be made here of the stratigraphically diagnostic *Edmondia*

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punctatella, found both in natural sections and in a boring in Fifeshire. In the Millstone Grit of the western part of the same county a rich marine fauna was obtained, which on examination proved to belong to the Upper Carboniferous fauna of North American facies described by the late Dr. Wheelton Hind from Central Scotland.

Mr. S. S. Buckman has completed his examination of the Jurassic ammonites collected in Ardnamurchan, western Argyllshire. Mention was made in last year's 'Summary of Progress' of two new ammonites found in the Raasay Ironstone position of that district, and these have proved of special interest in their bearing on the date of the deposit. Mr. Buckman had suggested, in one of the Survey Memoirs, that in the type district of Raasay the Ironstone might be really conglomeratic, with *Hildoceras bifrons* (d'Orb.) as the latest of the ammonites yet found in it. The Ironstone position in Ardnamurchan contains derived *Dactylioceras* of the Falciferum Zone, while the two ammonites referred to disclose a fauna of *striatulum* date, showing the great gap in time between the ironstone and its shale-pavement of *falciferum* date.

It is also from his examination of Ardnamurchan materials that Mr. Buckman is able to detect the presence of the Moorei Zone, which has so far not been recognized in Scotland, and he finds that the Discites Zone of that district is rich in fossils and is capable of being subdivided.

The examination of the Jurassic rocks of North-East Scotland is completed, and the results obtained will appear in a forthcoming Memoir.

F. L. KITCHIN.

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VI.—MUSEUM OF PRACTICAL GEOLOGY

Museum work has been seriously curtailed by the repairs to the roof of the building. The erection of a temporary tower at the north end of the Museum has disorganised the stored and exhibited collections and has interrupted the work of developing the economic exhibits. The public have been, of necessity, excluded from the building and it has been impossible to give demonstrations and lectures to scientific societies and clubs.

The Sixth International Mining Exhibition was held in May, 1923, and for this the Museum staff prepared an exhibit of Survey maps, memoirs and specimens. Preparations have been made to illustrate the work of the Survey and Museum at the British Empire Exhibition to be held at Wembley in 1924.

A new edition of the ' Guide to the Collection of Gemstones ' has been issued.

An investigation was made into the occurrence of the rare mineral, petalite, in the Meldon aplite, Devonshire, and the results published in the Mineralogical Magazine.

The Curator attended the conference of the Museums Association at Hull and read a paper on Gemstones in Museum Collections, since published in the Museums Journal.

Numerous additions, by purchase, donation and exchange have been made to the library, and the congestion has been partially relieved by the transfer of 1,100 volumes to an adjacent corridor fitted with shelving for the purpose.

In the Mineral Department the work of cleaning and registration has been continued and further progress has been made with the description of the bedded ironstones by Mr. Hallimond, who has also taken the opportunity of examining certain sections in the field.

The boring at Adisham in Kent was visited and specimens of the ferruginous Kellaways beds were collected. These prove to be a series of sands carrying limonite ooliths with more or less clay, while the top bed is cemented with calcite, forming a sandy limestone. The rocks are distinctly less ferrous in character than at Fredville, and the group furnishes a passage from the chamosite-siderite type to the ' iron-shot ' sands.

The iron ores at Westbury and Seend were examined. The latter proves to contain a considerable amount of ferrous carbonate and is not simply an ' iron pan.' The Greensand was here probably originally ferruginous ; it contains much glauconite which in some grains is quite fresh, though generally altered, together with small ' iron-shot ' concretions of limonite and pebbles of a whitish fine-grained sideritic mudstone, also fragments of limonitic grit ; the interstices are filled with coarse cementing siderite. In the upper part the bed contains limonitic crusts and ' boxes ' due to weathering. The Westbury Ironstone was found to contain

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small grains of siderite and limonite ooliths in a matrix of chamosite mud.

For comparison with other greensand rocks the peculiar ferruginous Lower Greensand at Midhurst was collected. This bed proves to be comparable with those in the Kellaways and at Seend, and is a quartz sand containing limonite ooliths, fragments of limonitic grit and oxidised siderite mudstone, but there is practically no cement and the ferrous compounds are absent. Unaltered glauconite occurs, so that this deposit also is apparently primary and is not due to the oxidation of a greensand.

A short period was spent in examining the Marlstone at Banbury and in Lincolnshire and Leicestershire, with a view to testing the theory that the iron-content was due to secondary enrichment and not merely to the removal of the calcite by leaching. With the exception of limonitic crusts in very highly weathered stone there is a noteworthy absence of richly ferruginous material; the alteration is very uniform and general; fibrous goethite is extremely rare, the greater part of the oxidised ore consisting of a spongy limonitic material which retains the structure and bulk of the original rock. Calcite has been removed, but apart from minor redistribution in crusts there is no indication of an increase in the average iron-content as compared with that of a similar bulk of unweathered green stone. The harder stone which often forms the upper part of the bed is a shelly limestone, with rhombs and patches of siderite (of pene-contemporaneous formation) in the cementing calcite. This rock breaks down into a shingly ore on weathering and it is not possible to say that no enrichment has then occurred, though by analogy it would be natural to assume that here also the iron is original. At Astrop, near Kings Sutton, Banbury, the lower green ore contains abundant pebbles of chamosite mudstone, resembling a shale, but relatively free from detrital quartz. Another interesting conglomeratic bed occurs at Gonerby and Barkston, north of Grantham, and there is a similar development in the Cleveland ironstone.

The well-exposed dip slope N.W. of Melton Mowbray affords an excellent example of uniform weathering, with removal of calcite. Most of the quarries in this area were visited, but in no case was any exceptional concentration of limonite observed, such as would be expected if the iron had been brought in by percolating waters.

More or less compact bedded ironstones containing chiefly ferric oxide have generally been termed hæmatites; they are sometimes bright red in colour, but the analyses show the presence of combined water, so that they are probably to be classed as turgite. A bed of this type occurs at the base of the Coal Measures, north of Cheadle, in Staffs. Specimens collected on a visit to this locality show that, in addition to the calcitic facies worked many years ago and analysed for the ' Iron Ores of Great Britain,' the

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bed passes laterally into a clay rock with little or no calcite. In the microsection the iron oxide assumes the distinctive form of a mat of irregular branching vermicular growths ; of which the interstices are filled with calcite and dolomite or, alternatively, with a matrix of fine quartz and clay identical with ordinary Lower Coal Measures clay. At Consall Bridge Station the base of the Coal Measures is now exposed in a small stone quarry, and the hæmatite bed, commonly stated to be a lenticle, proves to have divided into several thin beds or courses of nodules, separated by about six feet of clay from the underlying Grit and visible upwards for about fifteen feet. These courses externally resemble ordinary Coal Measures siderites, but are entirely different in composition and microstructure. A specimen of streaky green and brown clay, obtained from the drift at Consall Station, contains layers sparsely or thickly set with the vermicular oxide, to which their red tint is due. Apparently the ironstone is of contemporaneous formation, possibly due to an intensification of the conditions which give rise to the red marls at other horizons in the Coal Measures. For comparison the Etruria Marl was examined ; limonite ' shot ' are infrequent but were sometimes found mingled with calcite pisoliths. In the quarry south of the Etruria-Newcastle road a hard bed about nine inches thick is exposed for about twenty yards. This bed consists of small rounded pebbles of a granular calcitic marl, more or less deeply coloured by iron oxide and closely set in a matrix of milk-white barytes. The latter extends in large ophitic crystals which occupy the greater part of the interstitial space and terminate in well-marked crystal outlines against ordinary iron-stained marl which fills the narrow remaining spaces. Specimens of the Etruria Marl itself prove to be coloured with fine divided oxide, the clay being relatively free from staining ; the oxide sometimes assumes vermicular forms recalling those in the Cheadle hæmatite.

Mr. Hallimond finds that the preparation of microsections of the clays and other soft rocks has been facilitated by the use of a ' synthetic resin ' for infiltrating the material before sectioning. Since the clays are readily disintegrated by water, it has been found advantageous to finish the sections by grinding on dry emery papers. The following method of sectioning is at present in use for these rocks.

Preparation.—About 20 cc. of metacresol is warmed in a wide boiling-tube with a few drops of strong ammonia. To this is added 10 cc. of formalin (40 per cent. of formaldehyde) and the mixture is carefully boiled with constant shaking until a certain amount of the water has been driven off and the liquid does not separate into layers on standing, though it may be opalescent. At this stage a lemon yellow tint appears. The medium is conveniently kept in the tube, which is covered with a flat cork through which passes a glass dipping rod.

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In thin sections the material has a slight lemon-yellow colour and is isotropic; the refractive index, about 1·62, renders it well adapted for clearing the ground-mass of a clay or chamositic mudstone.

Imbedding.—The rock or clay to be sectioned is roughly flattened to form the face on which the section is to be made. With this surface uppermost the piece is placed in an air oven at a temperature of about 130°C. After a minute or so several drops of the medium are placed on the hot surface. These run quickly over the specimen and, if it is porous, may wholly disappear in the pores.

After being heated for from two to five minutes, according to the heat of the oven, the specimen is taken out and is ready for grinding. If porous, the piece should be given repeated treatments with the medium until it will absorb no more.

Grinding.—Any excess of medium may be scraped away with a knife from the harder rocks or may be ground off with coarse emery paper (FF). The surface is finally ground on French emery paper No. 1, and finished on No. 00, the emery papers being laid on a sheet of flat glass. At this stage it should be possible to distinguish the main structures on the polished surface with a hand lens. It is essential that enough of the rough surface should be removed to get to the bottom of any pits that may have been filled up with the medium. For example, in oolitic rocks the ooliths at the surface have commonly been damaged in the rough grinding before imbedding and must be ground away.

The flat surface is then mounted on a glass slip in the usual way (plate glass is to be preferred) and ground down with carborundum and water as far as possible, then dried by gently warming and finished on the emery papers as above. Before using the emery paper all exposed balsam at the edges should be scraped away, as this clogs the emery paper very quickly. The balsam used should be as hard as possible, and care must be taken to obtain close contact with the glass slip. The sections should be covered with cold xylol balsam as they often break up on reheating.

W. F. P. McLintock.

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APPENDIX I

On the Faunal Sequence of the Carboniferous Rocks met in the Roddymoor Boring, Co. Durham

By G. W. Lee, D.Sc.

The main features resulting from the examination of the cores of the Roddymoor Colliery boring, near Crook, Co. Durham, have been described by Dr. D. Woolacott in an article contributed to the 'Geological Magazine' (vol. lx., Feb. 1923, pp. 50–62). The present note deals only with the sequence of the principal Carboniferous fossils obtained when the core was broken up by Mr. D. Tait, of the Geological Survey, after Dr Woolacott's original examination.

The boring, undertaken in order to determine the coal-bearing possibilities of the Carboniferous Limestone Series of the district, started at the bottom of the Emma Pit, Roddymoor Colliery, 289 ft. below surface, and 190 ft. below the 'Brockwell' seam, which belongs to the Coal Measures.

The boring stopped at 2,911 ft., the last 83 ft. 6 ins. being through folded and contorted slates of Lower Palæozoic age. These slates are unfossiliferous, and therefore not definitely classifiable, but their lithological characters agree closely with those of the Skiddaw Slates, according to Dr. Woolacott and the other authorities who saw specimens.

The lowest Carboniferous Limestone rocks of the boring rest unconformably on the slates. Fossils were obtained from the limestones and calcareous shales included in Dr. Woolacott's Basement Conglomerate Series, but unfortunately they do not belong to species of zonal significance. The core from this horizon yielded *Spirifer*, Athyrid, Rhynchonellid, Orthotetid, *Pustula* of *punctata* type, *Chonetes* cf. *laguessiana* de Kon., *Aviculopecten clathratus*? (M'Coy) and *A.* cf. *perradiatus* de Kon.

Specimens obtained from the succeeding strata up to a thick white nodular limestone at the depth of 2,550 ft. are again of no diagnostic value. This white nodular limestone—falling within the Melmersby Scar Limestone series of Dr. Woolacott's table—has, on the other hand, yielded two interesting forms: one is an undoubted giganteid *Productus*, transverse, rather flat, of latissimoid aspect, but without spines; and the other, except for its large size, is undistinguishable from *Productus cora* Vaughan (*non* d'Orb. and others). The first is of value as indicating a position within the Visean, while the second—if accepted as a zonal fossil—would mark the 'S 2' Subzone of that stage.

The nodular limestone passes up into crinoidal limestone in which, 62 ft. above the position of the two *Producti* just mentioned, *Productus hemisphericus* J. Sow. was found associated with *P. striatus* (Fischer).

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In the 200 ft. of strata which succeed—mostly limestones and shales—fossils are rather scarce, the only noteworthy forms being a giganteid *Productus* and one resembling *P. longispinus* J. Sow.

At the depth of 2,280 ft. there occurs a remarkable bed made up of the closely packed shells of *Productus hemisphericus*, similar to the *Productus hemisphericus* Bed of Wharfedale in Yorkshire.

Strata overlying the *P. hemisphericus* Bed are fairly fossiliferous. Among others, the following were found : *Lithostrotion* cf. *martini* M. Edw., *Cleiothyridina roissyi* (L'Ev.), *Composita*, *Spirifer semicircularis* Phill., a transverse giganteid *Productus*, *P. undatus* Defr., etc.

Dr. Woolacott has identified the 'Jew' Limestone of the base of the Yoredale Series at the depth of 2,192 ft. It has yielded a few brachiopods, including a giganteid *Productus* and a small strange form suggesting the young stage of *P. margaritatus* Phill. A little above it, *Zaphrentis*, *Chonetes laguessiana* de Kon., etc., and a *Bucanopsis* were found.

Productus latissimus J. Sow. of small size was obtained at the depth of 2,108 ft., and it is interesting to note the presence, 14 ft. above it, of the plant *Bothrodendron kidstoni* Weiss., so far only recorded from the Calciferous Sandstone Series of Scotland.

Obscurely preserved lamellibranchs referable in part to *Myalina* form a conspicuous band at 2,092 ft. A thick limestone which follows—the Tyne Bottom Limestone of Dr. Woolacott's table—contains corals, mostly obscured by calcification, including a *Syringopora* characterized by its small corallites and *Lithostrotion portlocki* M. Edw., and it has moreover yielded the only representative of the typical form of *Productus giganteus* (Mart.). A few specimens obtained in the strata immediately overlying the Tyne Bottom Limestone are not specifically determinable.

Hard grey shale at 1,955 ft. from surface contained *Solenomorpha parallela* (Hind) besides two other lamellibranchs doubtfully suggesting *Streblopteria* and *Nuculana*.

Lithostrotion junceum (Flem.) and a fragment of a transverse giganteid *Productus* are the only fossils recorded from the 'Cockle Shell' Limestone. There are no specimens from the lower portion of the 'Scar' Limestone, but its upper portion, resting on the top of the Whin Sill, shows a small form of *Productus latissimus* J. Sow. without spines, accompanied by an indeterminable shell possibly belonging to the *Pustula punctata* group.

The limestone referred to the 'Five Yards' Limestone is fossiliferous, and its fauna is represented here by *Lithostrotion junceum* (Flem.), a Stenoporid characterized by having oblique zoecia, a *Fenestella*, *Camarotoechia pleurodon* (Phill.), *Pugnax pugnus* (Mart.), *Cleiothyridina roissyi* (L'Ev.), *Pustula aculeata* (Mart.), *Productus* cf. *costatus* J. de C. Sow. and *P. latissimus* J. Sow.

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Lepidophloios scoticus Kidst., a plant common in the Oil Shale Series of Scotland, was found in the burnt shale overlying the limestone. A number of fossils occur in a limestone 4 ft. 4 in. thick correlated with the ' Three Yards ' Limestone, as well as in the strata immediately above and below it. They belong to *Dibunophyllum*, a fine-meshed *Fenestella*, *Orbiculoidea nitida* (Phill.), *Spirifer* cf. *triangularis* (Mart.), a finely striated *Spirifer*, ? *Cleiothyridina roissyi*, *Productus longispinus* J. Sow., *P. latissimus*, a *Productus* resembling *P. muricatus* Phill., but with sharper ribs, *P. sp.* with fine nodulose ribbing, *Streblopteria laevigata* (M'Coy), *Syncyclonema sowerbyi* (M'Coy), etc.

The strata which separate the last-named position from that of the ' Great Limestone ' are practically unfossiliferous : of the few forms found the most interesting is *Posidonomya corrugata* Eth., which is far more commonly recorded in Scotland than in England.

The core of the ' Great Limestone ' was barren of fossils, except at the top, where the only specifically determinable fossil was *Euphemus urei* (Flem.), accompanied by *Productus*, a Rhynchonellid and a doubtful *Protoschizodus*.

Brachiopods constitute the bulk of the fauna observed in the thick series of strata between the ' Great Limestone ' and the ' Fell Top ' Limestone. The better preserved specimens belong to *Spirifer triangularis* (Mart.), *Cleiothyridina roissyi* (L'Ev.), *Productus longispinus* J. Sow., *P.* cf. *productus* (Mart.), and *Pustula* cf. *pustulosa* (Phill.). Of the few lamellibranchs present, a striate form of *Grammatodon*, *Streblopteria* aff. *ornata* (Eth.), and *Edmondia sulcata* (Phill.) may be cited.

The ' Fell Top ' Limestone contains *Productus antiquatus* J. Sow., *Pustula* cf. *punctata*, and a large transverse giganteid *Productus*, concentrically wrinkled, apparently finely striated, not furrowed, of the shape and size of the specimen figured by Davidson, Pl. 39, Fig. 1.[1]

There are numerous marine horizons throughout the Millstone Grit Series. Near the base crinoid stems, *Spirifer*, *Rhipidomella*, an Orthotetid, *Productus*, *Conularia*, and *Phillipsia eichwaldi* (Fischer) were obtained.

Shales and thin limestones between the depths of 618 ft. and 670 ft., that is, not quite half way up the series, have yielded a number of specimens, not always determinable ; the most interesting are *Productus anthrax* Hind and *P.* cf. *carbonarius* de Kon. ; the former species was founded on Coal Measures specimens, while the latter, which is rare in Britain, was first described by de Koninck from the ' Ampélite ' of Choquier above the Visean of Belgium. *Productus* cf. *concinnus* J. Sow., *Spiriferina octoplicata* (J. de C. Sow.) and other brachiopods are

[1] Davidson, T., 'British Fossil Brachiopoda' (*Palæontographical Society*), vol. ii, 1862.

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also represented, as well as *Serpula* and *Euphemus*. Higher up—a little above the middle of the series—marine conditions are indicated by the presence of *Serpula*, *Orbiculoidea nitida* (Phill.), *Productus* and *Bucanopsis*.

Lingula mytiloides J. Sow., *Productus carbonarius* and *Bucanopsis* characterize a still higher marine horizon. The following were found at the depth of 311 ft. in the top portion of the core, referred to the base of the Lower Coal Measures by Dr. Woolacott: Orthotetid, *Buxtonia scabricula* (Mart.), *Productus* cf. *productus* (Mart.), *Nucula*, *Palaeolima?* and *Phillipsia*.

To sum up the above remarks, it will be seen that the bottom part of the bore has not yielded any zonal forms which could fix the date of the unconformity, but the record of giganteid *Producti* 300 ft. above it would suggest that little, if any, of the Carboniferous Limestone here is earlier than Bernician. The finer zonal subdivisions of the Carboniferous Limestone used elsewhere are not applicable in the case of this boring owing to the insufficiency of diagnostic forms, though a high position is indicated in a general way.

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APPENDIX II

THE SOUTH-WESTERLY THICKENING OF THE MILLSTONE GRIT IN LANCASHIRE.

BY LAURANCE H. TONKS and W. B. WRIGHT

Introduction

Considerable activity in water boring followed the prolonged drought of 1921, and valuable geological information has been obtained from visits to these borings. A great accumulation of boring records has also come to hand. We have to thank Mr. J. K. Swales, M.Inst.C.E., Waterworks Engineer at Bolton, for permission to visit new boreholes south of Belmont, and for many old records; Mr. J. Woodhead Smith, A.M.Inst.C.E., Waterworks Engineer at Bury, for permission to see the cores of the Gin Hall Reservoir Boring, and for old records; the Horwich Urban District Council for permission to visit their boring in Tuprow quarry; and Mr. J. Spencer, F.G.S., of Accrington, for many old records of boreholes and quarry sections in and around Rossendale.

In this note the beds between the Woodhead Hill Rock and the Main Third Grit are described. Comparison is made between the development of these beds in the Horwich-Belmont areas and their development in the Cliviger valley and Todmorden district. This is facilitated by the detailed information now at our disposal in the intermediate Rawtenstall-Ramsbottom area, but detailed discussion of this central area is postponed to the forthcoming memoir.

Careful study of the stratigraphical succession shows that there is a broad correspondence in types of sedimentation over the whole area, but the range of variation is so great and often so unexpected that correlations cannot safely be made on lithological grounds alone. An excellent method of correlation is, however, afforded by the marine bands which occur at different horizons. The constancy of these bands has been proved again and again, and, thanks to the work of Mr. W. S. Bisat on the equivalent beds of Yorkshire, the faunal succession represented by them is now so thoroughly understood that there remains little or no chance of confusion between them. Publication of specific descriptions by Mr. Bisat is pending, and for the present purpose the different bands will be referred to as follows :—

A mutation of *Glyphioceras reticulatum* (Phill.) occurs in bands above and below what was formerly known as the 'Third Grit.' The band below will be referred to as the B marine band, and those immediately above the grit as B′ and B″. A further mutation above these will be known as C. The bands associated with the Holcombe Brook Series, the Haslingden Flags, and the Six Inch Mine, may conveniently be called by the names of the

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series in which they occur. They are characterised by species of *Gastrioceras* of which only one, *G. cancellatum* Bisat, of the Holcombe Brook band has, up to the present, been described. This bed also contains the same late mutation of *Glyphioceras reticulatum* as is found in C.

The recognition of these marine bands gives a correlation independent of all accidents of lithology, and enables us to make a detailed comparison from place to place which would otherwise have been either impossible or fraught with considerable danger. The correlation of these bands can be followed out on the diagram (Fig. 14) and may be regarded as absolute.

The accompanying vertical sections summarise the succession in the different districts. The Horwich-Belmont section has been drawn up from the Tuprow borehole, near Horwich, and from the Lower Heights borehole, south-west of Belmont. In the latter boring no core was made until the uppermost bed of sandstone was reached. Sixty ft. of shale above this sandstone was not, therefore examined; but it is considered from evidence collected in the field, that this shale is at the horizon of the B′–C. marine bands. The section has been drawn so that it lies in its approximate position relative to the Horwich section. The Rossendale section has been constructed from quarrying information and from natural sections. This exposed succession is continued by the section of the borehole at Constable Lee, which has been placed in its proper position relatively to the section above. The Bury section is from the borehole at Gin Hall, near Bury; and the succession in Cliviger is that described by Mr. Lloyd in 1922.[1]

The correlation from north-east to south-west once established, there can be no question as to the thickening of the series as a whole in this direction. To make a similar statement with regard to individual beds is much more difficult because of the many doubts which arise as to the character of the lateral variation. A sandstone, for instance, may disappear in three distinct ways: by wedging out, by interdigitation, or by passage, and comparison of thickness has vastly different meanings in the three cases. In dealing with the comparative total thicknesses of strata between marine bands we obtain a result of considerably greater significance, because of the presumption of approximate original horizontality which attaches to these bands. That a high degree of probability attaches to such a presumption is apparent from various considerations.

(1) They persist over large areas.

(2) They are strikingly constant in their fauna and lithological character.

(3) They mostly occur a little above coal seams, which seem also to demand a position of horizontality for their formation.

This latter consideration requires a little expansion to make its

[1] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 50, Fig. 3.

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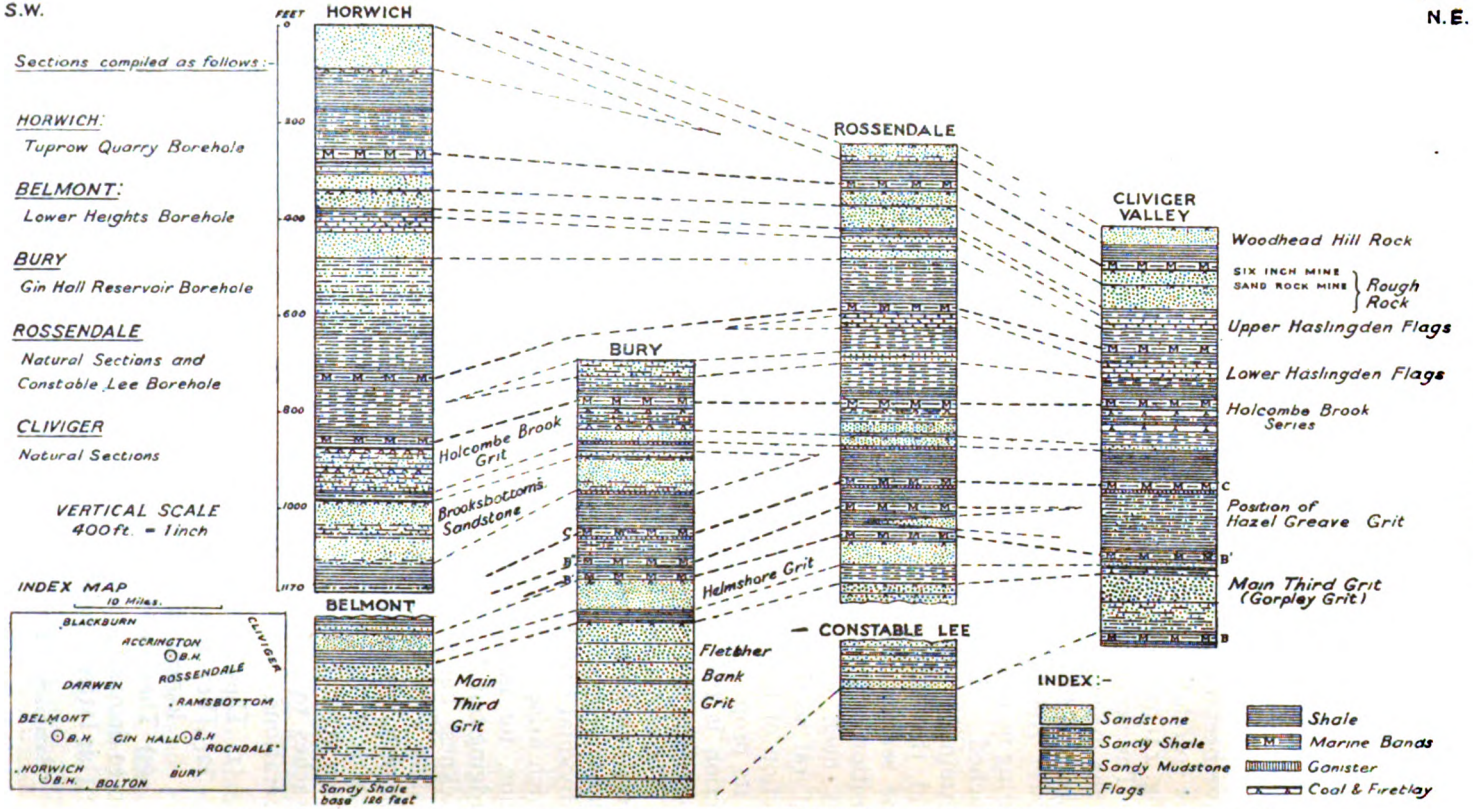

FIG. 14.—*Vertical Sections showing the South-westward Thickening of the Millstone Grit in Lancashire.*

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meaning clear. Under the general low lying conditions of the Coal Measures swamps, depressions in the coal forest must have harboured standing water. Elevations, on the other hand, would remain as such on the subsequent general submergence which led to the invasion of a marine fauna. In the first instance we might expect a cannel area in the seam, and in the second a failure, or profound modification of the marine band. The almost entire absence of such exceptional local conditions in the coals and marine bands is therefore strongly in favour of an original approximation to horizontality. Absolute horizontality cannot of course be postulated but departures from it seem likely to have been measurable in feet, possibly in tens of feet, but certainly not in hundreds.

Discussion of the Sections

The Fletcher Bank & Helmshore Grits.—The B marine band below the Third Grit is not exposed in the South-west, though the shales containing it were reached in the Constable Lee boring. The upper limit of this main Third Grit series is amply defined, however, by the B marine band, which has been recognised throughout the area. The Fletcher Bank or Main Grit of this series is a coarse pebbly rock occurring in massive beds, which are separated by partings of sandy shale, and impersistent coal seams and fireclays. This Grit is known to attain a thickness of over 360 ft., and a comparison of the Rossendale, Bury and Belmont sections shows that despite a certain thickening westwards the more important increase in thickness occurs in a southerly direction at this horizon.

A thin coal or fireclay is usually found on top of the upper bed of the Fletcher Bank Grit, and is succeeded by sandy shale and mudstone, separating the main mass of the Third Grit from its "upper leaf"; the Helmshore Grit. This is a finer grained and less massive bed; this character and the presence of the B′ marine band immediately above, are convenient distinctions between these two beds of grit.

The Beds above the Helmshore Grit.—In the west the B′ and B″ marine bands are separated by dark shale and shaly mudstone, but in the central area a thin flagstone and sandy shale series is intercalated at this horizon. Still farther east these sandy strata thicken and develop into a fine siliceous grit[1], the Hazel Greave Grit. *Pari passu* with this eastward development of sandy strata the B″ marine band dies out. The beds below the C marine band appear to participate in this easterly change to a sandy character, for in the west, in the section above Higher Hempshaws near Belmont as Mr. Jones has shown (see p. 63) the beds

[1] Wray, D. A., 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923. Fig 3.

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between the B′ and C marine bands are dark shale. There is here no representative of the coal and gannister band which occurs elsewhere below the C marine band, and no sandy beds are developed in this section.

The beds between the B′ and C marine bands form an interesting exception to the general rule of a south-westerly thickening. Their expansion is to the east and north-east, and is consistent with the increase in sandiness in this direction and the final incoming of the Hazel Greave Grit.

The Holcombe Brook and Brooksbottoms Series. — The Brooksbottoms and Holcombe Brook Sandstones occur together in the west, but both are not developed over the whole area. The Brooksbottoms Sandstone and the coal which occurs in its upper part disappear eastwards ; but westward the sandstone is doubled in thickness between Bury and Horwich. The Holcombe Brook Grit, at the base of the Holcombe Brook Series, is constant over the area. The beds succeeding it, which contain several coal and fireclay seams, are extremely variable in character, but their total thickness alters little. Constancy of development over a wide area reasserts itself with the Holcombe Brook Marine Band or zone of *Gastrioceras cancellatum*. Above this are shales and mudstones extending up to the base of the Haslingden Flag series.

The beds between the Holcombe Brook and C marine bands, both of which are well defined throughout the area dealt with, afford a good basis for a comparison of thicknesses. A steady expansion is noticeable from Rossendale south-west. It is, moreover, seen to be due to the incoming and steady expansion of the Brooksbottoms Sandstone, and, to a lesser extent, to the thickening of the Holcombe Brook Grit. The other strata, though showing variations in detail, alter little in thickness.

The Haslingden Flags and Rough Rock.—The mudstones at the top of the Holcombe Brook Series pass upwards without any sharp line of demarcation into the Haslingden Flags of Lancashire. These are everywhere divisible into upper and lower groups, separated by shales and mudstones with a very thin but constant marine band. The Lower Flags reach their maximum development in Rossendale, and, in agreement with this, the interval between the above-mentioned marine band and that of the Holcombe Brook Series below is seen to expand from Cliviger to Rossendale, and to contract again to the south-west. The Upper Flags, on the other hand, show a steady increase in thickness towards the south-west.

The Rough Rock, as a whole, maintains a fairly constant thickness over the whole area ; but it is perhaps noteworthy that the lower part, below the Sand Rock Mine, is somewhat thinner in the central and south-western districts, where the Upper Haslingden Flags are thick. The top of the Rough Rock is marked by a coal (the Six Inch Mine) and a marine band, which is everywhere

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traceable and easily recognised, although the preservation of the goniatites in it is hardly good enough to permit of specific distinctions. This band forms a convenient datum line for a comparison of thicknesses. It will be seen that the strata between it and the Haslingden Flag Marine Band below show an enormous expansion to the south-west. This expansion is due not only to the development of the Upper Flags, but also to a general increase in sandiness of the whole series of mudstones, which make up the rest of the strata between these two horizons. There is in fact no sharp lithological distinction between sandy mudstones and flags, which have repeatedly been found to pass laterally into one another.

Base of the Lower Coal Measures.—The shales above the Six Inch Mine Marine Band become sandy and increase considerably in thickness south-westwards; and this thickening is further accentuated by the western development of a coarse massive grit slightly below the horizon of the Woodhead Hill Rock. The latter rock, identifiable everywhere by the overlying Bassy Mine, with its accompanying *Carbonicola* bed, can be traced throughout the area, but fades off considerably in strength towards the west. In the south-west, however, between Holcombe Brook and Horwich, a massive rather felspathic sandstone, the Horwich or Ousel Nest Grit, develops below it, but is always separated from it by a thickness of grey mudstone. Its coarse and massive character led in the past to the identification of this grit with the Rough Rock. Detailed mapping in the field, the evidence afforded by marine bands, and new information from borings, have shown that it is intercalated in the series above the Rough Rock. This development sets in, and increases rapidly in thickness, southwards from Turton and westwards from Bury. The maximum thickness at present known was proved in the Horwich borehole.

General Conclusion

The comparisons instituted above, which owe their precision and significance in the main to careful palæontological correlation, lead to some interesting results. They demonstrate in the first place differential subsidence contemporaneous with deposition and varying from place to place. Moreover, subsidence does not appear to have been accompanied by deepening, but by excessive sedimentation. The two processes are clearly intimately connected, but which is cause and which effect we have at present no means of deciding.

In the repeated gradual vertical passage from shale, through mudstone to flags or shaly sandstone and vice versa, one sees clearly the effect of shoaling and deepening of deltaic waters, which may, however, have for its ultimate cause either sedimentation, or oscillation of level, or a combination of the two. The incoming of a coarse grit seems to be a phenomenon of another nature. It

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has been observed, for instance, that the base of the Rough Rock is often marked by a slight unconformity, and in all instances by a break in the character of the sedimentation.

The top bed of the Upper Haslingden Flags is succeeded by grey mudstone, in general followed by dark shale, on which the coarse pebbly grit of the Rough Rock rests. The gradual shoaling of the waters in this part of the area, which led to the deposition of the Upper Flagstone, appears, then, to have been succeeded by a reverse movement and deepening waters. The fine grade sediments, heralding this phase, are abruptly succeeded by coarse pebbly material of an inshore type. The base of the Rough Rock is exposed in many quarries, and the incoming of the grit material is accompanied by transgression of the Rough Rock base across the underlying beds. We are in this instance clearly face to face with something very different from the gradual shoaling mentioned above. Dr. Gilligan[1] suggests sudden uplift as an explanation, but it is by no means clear that it is necessary. Possibly the suddeness of the change and the slight erosion by which it is accompanied may be merely due to the lateral growth of the delta front.

Without covering a very much larger area than that dealt with in the present paper, and thus running the risk of defective correlation, it seems impossible to draw any general conclusions as to the form of the Upper Carboniferous delta and the source of its material. It is obvious, however, that the south-westerly thickening in South Lancashire contrasts strikingly with the northerly thickening established by Dr. Gilligan in Yorkshire; and must, to some extent at any rate, modify our conceptions of the form of this delta.

In conclusion, it should be noted that the facts established in this paper are of importance in relation to the problems of water finding. The Main Third (Gorpley or Fletcher Bank) Grit, which is generally found to yield a copious supply, is easily reached towards the north-east by borings starting on any higher horizon in the Millstone Grit Series. In the south-west it becomes increasingly difficult of attainment, and the necessity of finding sites where boring can start on relatively low horizons becomes insistent. At the same time, the thickening and increased coarseness and massiveness of the grit make it an improving reservoir in this direction.

The incoming and progressive development of the Brooksbottoms Sandstone towards the south-west affords a source of supply which is more easily reached, but can hardly be expected to be as copious as that of the larger grit below. It has, however, been found to give a satisfactory yield at Horwich, a result due, no doubt, to its highly jointed nature.

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[1] 'The Petrography of the Millstone Grit of Yorkshire,' *Quart. Journ. Geol. Soc.*, vol. lxxv, 1919, p. 283.

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The rapid development of the Horwich or Ousel Nest Grit in the south-west also promises a still more accessible source of supply in this area, but its capacity has not yet been tested.

It is essential that seekers for underground water in this district should ascertain as accurately as possible the stratigraphical horizon at which it is proposed to start boring. Otherwise disappointment and failure may ensue.

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